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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 491

Contribution from Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER June 30, 1917

THE MELON FLY IN HAWAII

By

E. A. BACK, Entomologist, and C. E. PEMBERTON,
Scientific Assistant, Mediterranean and other
Fruit Fly Investigations

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INTRODUCTION.

The melon fly (*Bactrocera cucurbitae* Coq.) (fig. 1) is a pest introduced into the Hawaiian Islands from the Orient, about 1895. As shown by the reports of the quarantine officers of the Federal Horticultural Board, it is being continually intercepted at the port of San Francisco in cargoes arriving from Honolulu, and there is danger that it will be introduced into continental United States. Together with the Mediterranean fruit fly (*Ceratitis capitata* Wied.), also recently introduced, it has had a most ruinous effect upon horticultural pursuits of Hawaii. The equable climate and abundant food supply have given this pest an excellent opportunity to increase unmolested and, at the time the writers undertook the investigation herein reported, the melon fly had made impossible a free cultivation of the most valuable, economically, of the Cucurbitaceae and other truck crops. No natural agencies have thus far been discovered which serve as a practical check upon its ravages, and artificial methods of control, especially control by poisoned-bait sprays, have been found inadequate, owing

to the lack of concerted and intelligent action among the oriental market gardeners. The purpose of this bulletin is, therefore, to call attention to the unprecedented ravages of this pest in the Hawaiian Islands and the danger of introducing it into the mainland United States, and to record new facts concerning its biology, rather than to offer a satisfactory method of control.

ORIGIN.

The true Dacinae, the subfamily of the Trypetidae, to which the melon fly belongs, are almost without exception tropical or subtropical in distribution. Most of the well-defined genera have been found by Bezzi to show a restricted area of habitation and to be almost exclusively confined to the Old World. Indeed, the few species which

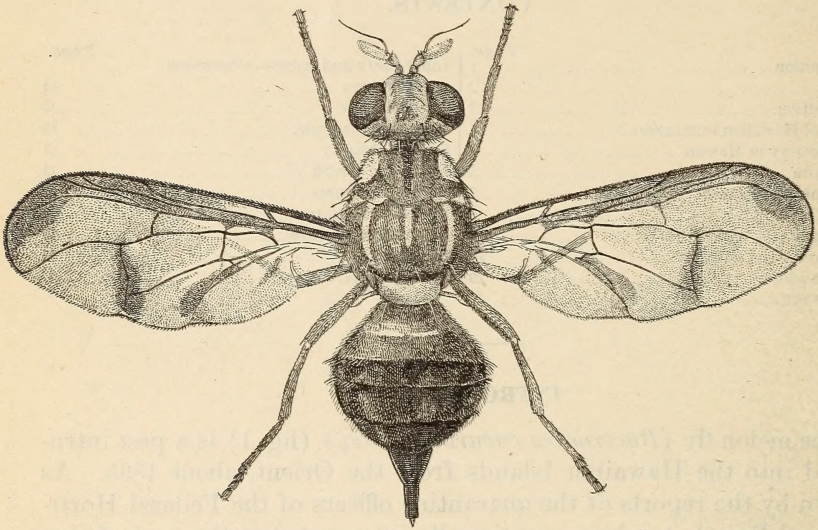


FIG. 1.—The melon fly (*Bactrocera cucurbitae*) : Adult female. Greatly enlarged. (Original.)

are recorded from widely separated countries have reached their present distribution not by natural spread but by the assistance of man. The melon fly is a good example of a pest known to have been artificially introduced to new countries. Bezzi, who has given the most complete and recent review of fruit flies, stated in 1913 that the original home of the melon fly is India. Other entomologists who have traveled in the Orient for the purpose of making fruit-fly studies, particularly Compere, Froggatt, and Muir, agree with Bezzi as to its Indian origin. Perkins stated that its true home is either Japan or China, but this statement was made in 1902, before the discovery of the melon fly in India and before the studies of Bezzi were undertaken.

DISTRIBUTION.

The melon fly has been recorded from India, Ceylon, Java, Timor, Australia, the Philippines, Singapore, southern China, Japan, and the Hawaiian Islands. The references known to the writers of its presence in these countries are as follows:

India.—Compere first recorded the melon fly from India, where he collected specimens in and about Poona on September 28, 1903, and at Bangalore in 1916. Froggatt (26)[1] in 1909 states that, in the company of F. M. Howlett, he noted the pest in the gardens at Allahabad during May, 1909. Bezzi (36) in 1913, while studying the fruit-fly material in the Indian Museum, found pinned material collected at the following places in India: Many specimens from Calcutta, taken in April, May, June, and September; others from Durjhana, Nepal, the Terai, Ranchi, Jhansi, northwestern India, 850 feet (Brunetti); Katihar, Purneah District, northern Bengal, in October; Allahabad, United Provinces, in August; Nepalganj, Nepal Frontier, January 22, 1911; Siripur; Saran, northern Bengal, September 26, 1910; Adra, Manbhum District, October 12, 1909; and in Bombay, in gourds, October 12, 1903. Maxwell-Lefroy (18) in 1907 states that this is a sporadic and occasionally a serious pest and gives as its distribution Nasik, Pusa, Surat, Umballa, and "probably throughout India."

Ceylon.—The melon fly appears to be generally distributed throughout Ceylon. Green (34), in 1912, and Rutherford (40), in 1914, list it among insects of economic importance. Bezzi (36), in 1913, records specimens in the collection of the Indian Museum caught January 10 at Peradeniya. Froggatt (26) found the pest at Jaffna in 1908. Compere (33), in 1905, records specimens taken at Colombo.

Java.—The melon fly was reported by Dammerman (41) in 1914 from Java, where it is frequently a serious pest.

Timor.—Compere is our authority for the presence of the melon fly on this island.

Australia.—Hill (50), in 1915, has given the only record of the presence of the melon fly in Australia. He records it from the Northern Territory as a pest of melons, pumpkins, and marrows.

Philippine Islands.—Essig (35), in 1913, gives C. F. Baker as authority for the presence of the melon fly in the Philippines. Mr. F. Muir has recently informed the writers of its presence in these islands, and specimens have been received from Mr. McKay, of the Philippine Department of Agriculture. The melon fly was first noted about Manila by Compere.

Southern China.—Compere (33) states that about Macao and Canton, in 1909, he found the melon fly a serious pest but not doing

[1] The figures in parentheses refer to Bibliography, p. 57.

as much damage as in the Hawaiian Islands. He has also found it at Hongkong.

Singapore.—The melon fly was reported from Singapore by Compere.

Japan.—In 1905 Craw (13) stated that the melon fly was introduced to Hawaii from Japan. Compere reared adults from material collected in melons and cucumbers at Nagasaki according to data on file at the office of the chief quarantine officer of the port of San Francisco. Muir (38), in 1914, records the melon fly as injurious to cucurbits on the Island of Formosa.

Hawaiian Islands.—The first critical study of the melon fly was made from material collected by Compere (2) in 1898 at Honolulu. At the present time the pest is known to occur on all the important islands of the group.

SOURCE OF HAWAIIAN INFESTATION.

The melon fly was without doubt introduced into the Hawaiian Islands from Japan. The interceptions of this pest from Honolulu during the past few years at the port of San Francisco make it easy to understand its introduction at Honolulu from Japan, where the pest is known to occur in vegetables grown about Nagasaki, a port in direct communication with Honolulu and from which many Japanese immigrants arrived in the islands during past years. Alexander Craw, entomologist of the Hawaiian Board of Agriculture and Forestry, wrote (13) in 1905 that the melon fly had been unfortunately introduced at Honolulu a few years previously from Japan.

That the melon fly was actually introduced is well known to all the older inhabitants of the islands interested in agricultural pursuits. Excellent watermelons and cantaloupes were abundant and cheap in the Honolulu markets, and pumpkins in large quantities were used as food for stock by certain ranchmen. At the present time these fruits are imported from California or grown in restricted areas in the islands with great difficulty. The perfect condition of the calabashes made from gourds by the native Hawaiians is additional proof that the melon fly is an introduced pest. Utensils made of gourds at the present time bear deformities and surface defects peculiar to melon-fly attack.

EARLY HISTORY IN HAWAII.

The first authentic account of the presence and ravages of the melon fly in the Hawaiian Islands was given by Mr. Byron O. Clarke, commissioner of the Hawaiian Bureau of Agriculture during 1898. In October, 1897, soon after his arrival in Honolulu, Mr. Clarke attempted to grow cucurbits in the Kalihi district, but found [1]

[1] Correspondence, Bureau of Entomology, U. S. Dept. Agr., dated Jan. 16, 1916.

that a fly deposited eggs in the young shoots and that the developing larvæ killed the vines before they were a foot long. During December of the same year Mr. Clarke attempted the cultivation of summer squash, muskmelons, and tomatoes at a point about a mile north of the railroad station at Pearl City. That the pest which caused the destruction of these crops was what has since been called the melon fly was proved by the adults reared by Mr. Clarke during February, 1898. Mr. Clarke states that in 1897 the old gardens about Pearl City were thoroughly infested with the melon fly.

Correspondence (1) in the files of the present Hawaiian Board of Agriculture and Forestry prove that the melon fly was well established and doing damage on the island of Hawaii, about 192 miles by sea from Honolulu, as early as August, 1898, and that it was known to Prof. Koebele, at that time entomologist of the Hawaiian Bureau of Agriculture. Mr. George Compere, who visited Honolulu during November, 1898, found the melon fly doing great damage to the truck crops grown by the Orientals in the Moiliili and Waikiki districts of Honolulu and collected the first material that found its way into collections for scientific study.

To Messrs. Compere and Clarke we are indebted for all existing information regarding the melon fly in the Hawaiian Islands prior to 1900. As Clarke has shown that serious injury was being done cucurbits as early as 1897 at Honolulu and at Laupahoehoe on the island of Hawaii in 1898, it is apparent that the introduction of the pest into the islands occurred at least several years earlier and that the pest was probably established on the other two important islands, Maui and Kauai, both of which are nearer Honolulu than Hawaii. The rapidity with which the Mediterranean fruit fly (*Ceratitis capitata* Wied.) has been known to spread since its introduction at Honolulu in very recent years leaves little doubt that the melon fly existed in the islands a comparatively short time before its ravages attracted the attention of agricultural officials. Perkins wrote (8) in 1902 that the melon fly was introduced "five or six years ago." It is safe to assume that the melon fly was present about Honolulu as early as 1895.

LITERATURE.

The melon fly was first described as a species new to science by Mr. D. W. Coquillett (2) in 1899 from specimens reared by Compere in Honolulu and forwarded to Dr. L. O. Howard, entomologist of the U. S. Department of Agriculture. Mr. Coquillett's article entitled "A new trypetid from Hawaii," published in Entomological News, contained the first information regarding the melon fly appearing in scientific literature. The first printed account (1) of its

ravages, however, appeared in "The Hawaiian," a newspaper published in Honolulu during 1898, and this is given in full in the bibliography. An article entitled "A dipterous enemy of cucurbits in the Hawaiian Islands," prepared by Dr. Howard (3) and published in 1900, is of importance, as it contains the first printed statements of melon-fly ravages to be found in scientific literature. Dr. Howard gives the substance of a letter written him under date of February 14, 1899, by Mr. Compere in Honolulu.

The bibliography (p. 57) contains all references to the melon fly known to the writers. Most of it is unimportant and is conspicuously meager, as shown by the attached summaries or verbatim quotations. Prof. M. Bezzi, in the Bolletino del Laboratorio di Zoologia, 1909 (24), and in the Memoirs of the Indian Museum, 1913 (36), has treated the systematic relationship of the melon fly. Banks (30), in 1912, gave the first technical and trustworthy description of the well-grown larva. All these references, with the exception of Coquillett's article already mentioned, deal with the economic status of the pest. For the most part they merely list the fly from certain localities and contain brief references to its capacity for damage to crops, or to the desirability of establishing or making more vigilant quarantine regulations. Thus Maxwell-Lefroy (18), Howlett (20), and Fletcher (43) give information regarding the pest in India; Green (34) and Rutherford (40) in Ceylon; Dammerman (41) in Java; Essig (35) in the Philippines; Muir (38) in Formosa; Hill (50) in Northern Australia, and Compere (33) and Froggatt (26) throughout the Orient in general.

The remaining references are from Hawaiian and California sources and are the result of the presence of the melon fly in Hawaii. From the quarantine standpoint the references of Craw (7) and Maskew (42) throw light on the present-day possibilities of spread. From a biological standpoint the references of Van Dine (19), Severin, Severin and Hartung (45), and Back and Pemberton (46) are the most important.

The article by Van Dine (19) contains a concise general account of the known facts concerning the melon fly published up to 1908, in addition to a complete bibliography and the first illustrations of adult, larva, eggs, and puparium. He states that the fly requires three weeks to pass through the egg, larval, and pupal stages. Severin (45), in September, 1914, published results and observations on the melon fly which may properly be called the first careful work done on the biology, extent of injury, and methods of control. This is the most important biologic paper published up to that time and contains so many new data that it should be possessed by investigators of the melon fly. The article by the writers (46) appearing

in December, 1914, gives the results of careful life-history studies and contains data on the various stages, accompanied for the first time by temperature records. The data contained in this last paper have been incorporated in the present bulletin.

While Van Dine has given us the first illustrations of the melon fly, others have been published. Howlett (20), in 1909, published a plate in Maxwell-Lefroy's "Indian Insect Life" containing an especially good figure of the adult female, besides figures of the egg, larva, puparia, and the anterior and posterior spiracles of the puparium. This plate was slightly enlarged and republished as a colored plate by Fletcher (43) in 1914, in "Some South Indian Insects." Perkins (29), in 1911, published a drawing by W. R. Potter of the adult female which was later used by Severin (45). Compere (33), Dammerman (41), and Bezzi (36) have published photographs of wings of the melon fly. Severin (45) included in his paper the first and only illustrations ever published of the damage to host plants caused by the melon-fly larvæ. These photographs were greatly reduced and much of their detail was lost. The only drawings showing larval details were published by Banks (30) in 1912, and included enlargements of the anterior spiracles, the stigmal plate, and a lateral view of the head.

ECONOMIC IMPORTANCE.

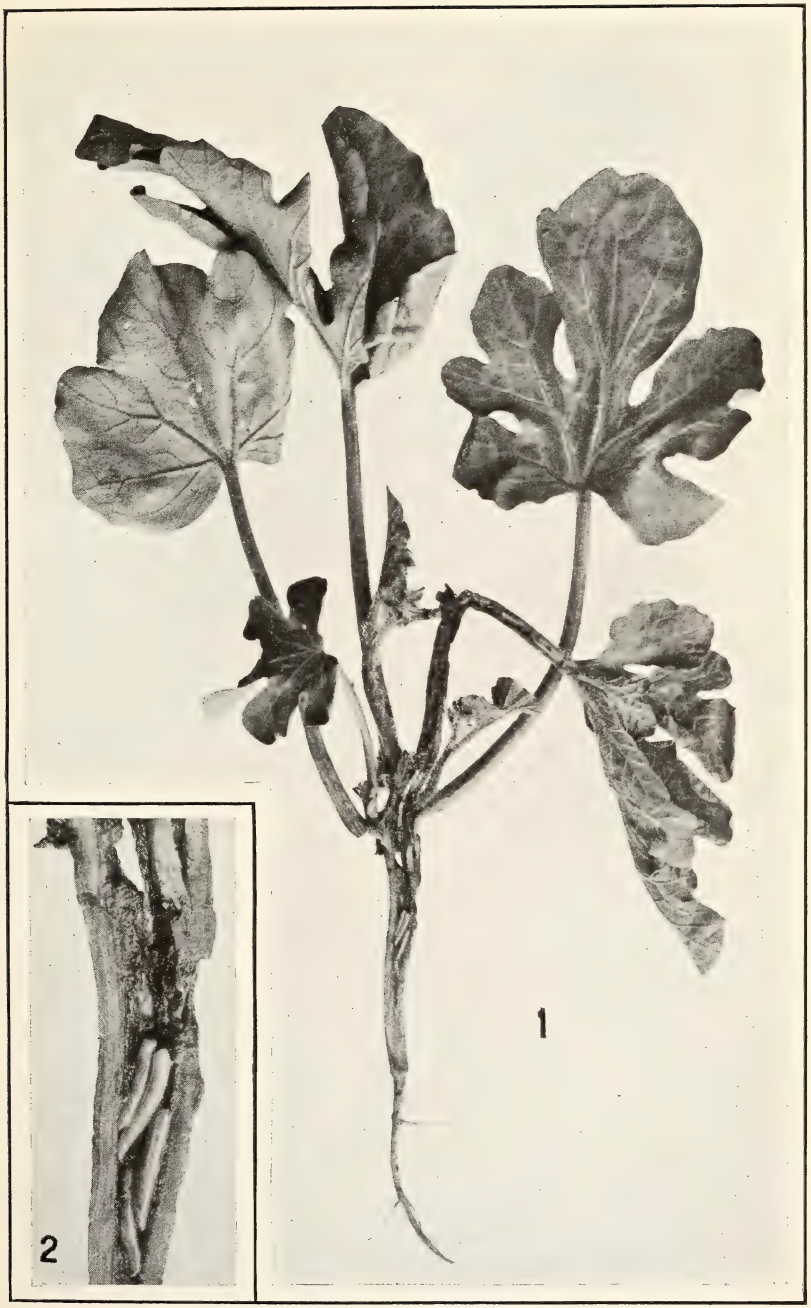
The melon fly is the most important pest of varieties of cucurbitaceous crops grown in the Hawaiian Islands. Its persistent attack has caused many to abandon the growing of its more susceptible host fruits, while others can be grown for the most part only under cover and at increased cost. The Mediterranean fruit fly (*Ceratitis capitata*) and the melon fly have ruined the free cultivation of fruits and vegetables in the Hawaiian Islands. Of the two pests, many consider the melon fly of the greater economic importance, as it attacks with greatest persistency those crops, such as squashes, pumpkins, and the vegetable marrows, which could otherwise be depended upon to furnish an abundant food supply for the poorer classes, and by its presence has ruined any trade with the coast in such vegetables as eggplant, peppers, etc. In 1902 Mr. Jared G. Smith, at that time director of the Hawaiian Agricultural Experiment Station, wrote (9) that the melon fly was doing great damage to cucurbits by stinging and depositing eggs in the young fruit. F. W. Terry (15), in 1906, in a preliminary account of insects of economic importance in Hawaii, wrote, "Since its arrival it has practically stopped the raising of melons, cucumbers, squashes, and tomatoes in many localities, unless these plants are carefully screened from the attack of the fly." Van Dine (11), in 1903, states that

"watermelons and muskmelons are a luxury; a good melon brings 50 cents to $1 at the fruit stands in Honolulu. These products could be raised in certain sections in quantities large enough to bring them within the reach of every table were it not for the attack of the melon fly." F. G. Krauss, formerly agriculturist of the College of Hawaii, stated (14) in 1905 that were it not for the ravages of cutworms, plant-lice, and the melon fly melons would be an excellent crop for Hawaii, but that the advantage of the favorable climate of Hawaii was offset by the prevalence of these pests. Blackman (22), in 1909, places the annual loss to market gardeners as the result of melon-fly attack at three-fourths of a million dollars. Severin (45) writes that "when one stops to consider that the Hawaiian Islands are smaller than the State of Rhode Island, that the principal agricultural products are sugar, pineapples, coffee, and rice, one realizes what a tremendous amount of injury this fruit fly causes to the limited vegetable crops grown in the islands." The truth of all the foregoing statements regarding the great damage caused by this pest and its right to first rank among the pests of the market gardener has been corroborated by the writers. It is not possible to overexaggerate its importance as a serious pest under Hawaiian littoral conditions.

INJURY.

Injury due to melon-fly attack is in the nature of deformities resulting (1) from punctures made in the epidermis of the host fruit or plant when no eggs are deposited; (2) when the eggs deposited or resulting larvæ fail either to develop or to penetrate the tissues deeply; and (3) from the destruction of plant tissue by the unhindered development of the larvæ. While the fruits of the host plant are always attacked with greatest severity, no portion of the plant is immune, particularly when succulent growths are produced by hot, moist weather conditions.

Injury to the root.—It has been stated (45) that in many localities the seeds of some cucurbits barely germinate before the seedlings are attacked by the melon-fly larvæ, which devour the tissues of the stem, causing decay, and penetrate the roots and completely destroy the plant. This type of injury (Pl. I) is by no means the most common, but has been observed by the writers on many occasions. The writers have never known the roots of seedlings of any host other than the watermelon to be thus attacked, and then only when the plants were very succulent. Entire fields of watermelons have been destroyed by such attacks during the warmer parts of the year in a badly affected area. At other seasons and in localities more isolated from habitations, or where no host fruits have been grown for some time, seedlings are not usually affected below the ground.



WORK OF LARVA OF THE MELON FLY (BATROCERA CUCURBITAE).

Watermelon seedling destroyed by larvæ of the melon fly feeding in the taproot, crown, and leaf petioles. Note that the leaf to the left is nearly severed from the crown, while the petiole of the drooping leaf has been completely tunneled by the larvæ. In figure 2 is shown, enlarged, the work of larvæ in the root. (Original.)

OVIPOSITION BY MELON FLY ON WATERMELON VINE.

Tip of a watermelon vine showing an adult melon fly ovipositing in the ovary of a flower still in bud, an unaffected male bloom, and the withered and drooping growing tip of the vine. A female melon fly has deposited eggs in the vine at the base of the leaf petiole, and the young larvæ hatching have nearly severed the vine at this point. (Original.)

DAMAGE TO WATERMELON VINE BY LARVÆ OF MELON FLY.

Succulent watermelon vine showing the blackened and decaying condition beyond the point of attack. The eggs from which the larvæ hatched were laid at the base of the fruit stalk shown in lower portion of figure. Note that small as the young watermelon is it has already become infested, as indicated by the blackened area. For condition existing within this vine, see Plate IV. (Original.)

WORK OF LARVÆ OF MELON FLY IN WATERMELON VINE.

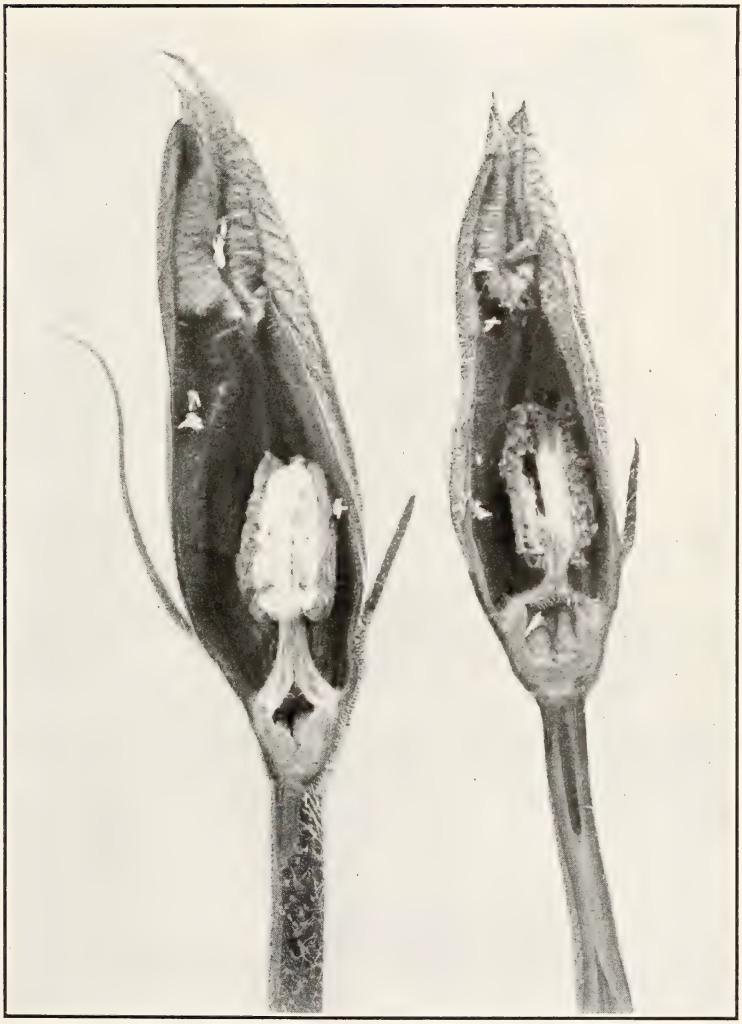
Succulent watermelon vine sectioned to expose well-grown larvæ of the melon fly which have eaten out the interior, causing the vine to wither and die back to the point of original infestation. (Original.)

CANTALOUPE VINE ATTACKED BY MELON FLY AND DAMAGE BY LARVÆ.

Cantaloupe vines and fruits are very susceptible to attack. The vine shown has been attacked in eight places, as indicated; the larvæ developing in the stalk, petioles, or young fruit. (Original.)

SQUASH VINES ABORTED BY WORK OF LARVÆ OF MELON FLY.

Squash vines affected by the larvæ of the melon fly. Sometimes, especially during wet weather, the female fly deposits eggs in the older stems. The young larvæ hatching do not seem to be able to kill the vine outright as they do the more succulent and rapidly growing vines, but as they mature they cause abnormal swellings to develop about them. As the vines throw out rootlets little injury is caused to squashes by this method of attack. (Original.)



MELON-FLY EGGS DEPOSITED IN BLOOMS OF PUMPKIN.

Two buds of the male bloom of pumpkin sectioned to expose melon-fly eggs deposited through the corolla. Note that larvæ from eggs already hatched are causing the destruction of the vital organs. (Original.)

RESULT OF INFESTATION OF PUMPKIN BLOOMS BY LARVÆ OF MELON FLY.

Buds of the male flowers of pumpkin affected by the larvæ of the melon fly. Figures 1, 2, and 3 represent the various stages in the destruction of the male bloom after the larvæ hatching from the eggs shown in Plate VII have begun to develop. In figure 1 the larvæ have destroyed the pollen and are devouring the receptacle. In figure 2 the inflorescence is hanging and the larvæ are still within, while figure 3 represents the final stage of destruction. During the warmer months of the year practically all male flowers are affected, although many succeed in blooming. (Original.)

WORK OF LARVÆ OF MELON FLY IN BLOOMS OF PUMPKIN.

In figures 1 and 2 is shown the work of the larvæ of the melon fly in bringing about the destruction of the ovaries of pumpkin bloom even before the corolla has entirely withered. Note that in figure 1 the corolla has not yet unfolded nor has the stigma been exposed. In figure 2 is shown the more complete destruction of the ovary of a flower, the corolla of which has but recently withered. (Original.)

DAMAGE TO SQUASH BY LARVÆ OF THE MELON FLY.

Cross sections of unfertilized ovaries of three squash fruits showing a type of infestation, progressing from figure 1 to figure 3, that brings about the complete destruction of the crop of many acres of squashes and pumpkins where no care is taken to guard against oviposition. Note that the slight infestation of figure 1 has extended up into the pistil of figure 2, while in figure 3 the larvæ have worked so rapidly that the ovary is breaking before the corolla can unfold. (Original.)

Injury to the foliage and stems.—The very disastrous effects of attack on the foliage is shown in Plate I, figure 1, where the petiole of a watermelon seedling has been tunneled by larvæ. Such complete destruction is not usual in older plants after the tissues have hardened. Larvæ developing in the pipelike petioles of large pumpkin leaves do almost no harm. The manner in which developing runners of watermelon seedlings may be killed back to the crown is illustrated by Plate XXI, figure 3. As the plants become older the crown becomes so toughened that it withstands attack, the growing tips of the vines, especially those of watermelon and cantaloupe, are seriously attacked, and the larvæ developing in the shoot cause its death beyond the point of infestation, as shown in Plate II, and thus bring about a progressive pruning. At the time infestation illustrated in Plate II occurred the growing shoot was so small that the puncture made by the female for her eggs practically cut the shoot and would have produced withering beyond had no further destruction been caused by the larvæ developing later. In Plates III and IV may be seen the type of injury to still older watermelon shoots. Note that the young fruit has begun to wither and that the stalk has already turned black and has become flabby to the touch, thus indicating that the interior has been destroyed. This destruction of the interior is shown by the shoot on Plate IV, which has been sectioned to expose the well-grown larvæ within. Such pruning back of foliage and shoots appears to occur more often among older cantaloupe vines than among watermelon vines of similar age. In Plate V is given, by way of illustration, a portion of a cantaloupe vine cut in the environs of Honolulu, showing attack in eight places. The field from which this vine was taken bore only small, stunted vines, in spite of the fact that the soil was rich.

Oviposition in the stems of host plants does not always produce the complete destruction illustrated, since very often the growth of plant tissues may be so rapid that the larvæ appear to be killed. Again, they are able to develop locally, reach their full development, and leave the plant without having affected vital injury. Under these conditions, however, the plant may develop an abnormal growth about the feeding larvæ. These abnormal developments of the vine have never been observed in any host plant but the pumpkin and squash, and then reach their fullest development only during wet weather. (See Pl. VI.) During dry weather, when the vines are tougher, little successful infestation of squash or pumpkin vines occurs.

Injury to the bloom.—It is difficult during the greater portion of the year in littoral Hawaii, especially on the island of Oahu, to find

an unaffected pistillate flower of any cucurbitaceous host plant growing naturally in the field. No staminate blooms of watermelons, cantaloupes, cucumbers, and certain Chinese marrows have been found affected, but those of the pumpkin and squash varieties are badly attacked. An examination of 207 well-developed buds of the male flowers in a field at Waialua during March, 1915, proved each bud to contain the eggs or larvæ of the melon fly. Plate VII represents the early stage of infestation of the male bloom of pumpkins. As the larvæ hatch they feed upon the receptacle and the anthers until the interior is a mass of decay. In the illustrations of Plate VIII are shown three stages in the destruction of the male bloom. In figure 1 the larvæ have destroyed the anthers and are burrowing about the receptacle; in figure 2 the continued work of the larvæ and the weight of the bud have caused the latter to break over, while figure 3 represents a very frequent condition after the bud has dropped to the ground, leaving behind a few larvæ within the upright flower stalk and carrying others within itself to the ground. When the male bloom is attacked late in its development the corolla unfolds normally, exposing to view unhatched eggs or very young larvæ on its inner surface or among the pollen grains. When buds are attacked before they are three-fourths developed they usually are destroyed before they can bloom. Eggs are never deposited in the flower while it is in bloom.

While injury to the corolla of the female bloom does occur in pumpkins to a limited extent, the attraction of the unfertilized ovaries is so much greater that this portion of the bloom receives the greater amount of oviposition, and infestations that prevent blooming occur within the ovaries rather than in the corolla and about the style and stigma. The greatest injury to pumpkin, squashes, watermelon, cantaloupes and *Momordica* spp. occurs at this stage, or directly before and after the flower unfolds, and is, to the uninformed, so obscure that the apparent sterility of fields of rankly growing vines is often the cause of discussion. The cross-sections of the bloom of pumpkins in Plate IX illustrate the disastrous result of this attack. In figure 1 the ovary has already been ruined by young larvæ before the corolla has opened to expose the stigma for fertilization. In figure 2 is shown a more advanced stage of infestation, but one occurring before the corolla has entirely withered or lost its color. The three figures on Plate X illustrate the progressive infestation of the pistillate bloom of squash. In these examples the larvæ have not only attacked the ovaries, but, as in figure 2, have worked their way up into the corolla. Often, in blooms of this type, the work of the larvæ, aided by decays started by them and the weight of the upper portion of the bloom, causes the ovaries to break off, as illus-

trated in figure 3. Such destruction is almost complete in uncared-for fields of all cucurbits except the cucumber, which rarely is attacked until after the fruits are well set.

Injury to the fruits after fertilization.—All degrees of injury will be found among the fruits of host plants. The younger the fruits, as a rule, the more susceptible they are to complete destruction by the larvæ and subsequent decays. If infestation is serious directly after the bloom has withered, particularly among watermelons in a dry location, a mummification of the fruits may result. (Pl. XI, fig. 1.) The completeness with which the young watermelons may be destroyed before mummification is shown by Plate XI, figure 2. Still older watermelon fruits may become badly infested, as illustrated by the longitudinal section in Plate XII and the cross-section in Plate XIII. In the latter the interior bearing the seeds had been reduced to a watery mass and the larvæ were found burrowing through the rind. In fruits such as those illustrated in Plates XII and XIII secondary decays soon bring about a complete destruction of the host.

The injury caused by the developing larvæ may not be so great as completely to destroy the host fruit. In such cases, especially among pumpkins and squashes, which are apt to develop a corky protective growth over the surface exposed by infestation, various and curious deformities are produced as illustrated by the young fruits shown in Plate XIV. In each of these fruits one or more colonies of melon-fly larvæ have reached maturity and emerged. The figures in Plates XV and XVI illustrate several types of injury to very young pumpkins. While these fruits will persist on the vines for several weeks during dry weather, they ultimately succumb to the secondary attacks of scavenger insects and decays.

As the fruits become larger, before they are attacked, they may show almost no indication of infestation to the casual observer, although there never is any doubt in the mind of a trained observer. An examination of such fruits may reveal the interior to be badly affected and eaten out, although the exterior remains firm. This is probably true more in the case of cucumbers and several varieties of Chinese marrows (*Momordica* spp.), and less so of string beans, as illustrated in Plate XVII. Injury to tomatoes, when the larvæ become about half grown, is usually accompanied by decay confined for some time to the section of the fruit affected.

Deformities resulting from punctures of the epidermis when no eggs are deposited, or from infestations by larvæ or eggs in only the outer portion of the rind.—Deformities of all sorts are produced in cucumbers and pumpkins which have been attacked late in their development. Deformities among watermelons have been noted by

the writers chiefly in small fruits as illustrated in Plate XVIII, figures 1 and 2. Deformities among cucumbers and squashes are illustrated in Plates XIX and XX. These injuries are most often the result of the irritating presence of batches of eggs or small colonies of larvæ present in the extreme outer portion of the fruit. Such deformities are serious injuries, as they prevent the full normal expansion of the fruit during growth, as will be appreciated when a comparison is made between figures 2 and 3, Plate XX, illustrating a badly deformed and a nearly perfect squash. Among watermelons and gourds deformities usually follow mortality among eggs and very young larvæ, discussed elsewhere (page 46), but among pumpkins and squashes they may develop about open wounds made by larvæ, as illustrated in Plate XX, figure 1. Early infestation of bean pods is evidenced frequently by a constriction in the pod at the point of oviposition.

FOOD PLANTS.

The food plants of the melon fly may be divided into those preferred and those occasionally infested and may be listed as follows:

PREFERRED, CULTIVATED.

1. Cantaloupe.
2. Watermelon.
3. Pumpkin.
4. Squash.
5. Gourds.
6. Chinese cucumber (*Momordica* sp.).
7. Chinese melon.
8. Cucumber.
9. Tomato.
10. String beans.
11. Cowpeas.

OCCASIONALLY INFESTED, CULTIVATED.

1. Eggplant.
2. Water lemon (*Passiflora*).
3. Orange.
4. Fig.
5. Papaya.
6. Peach.
7. Mango.
8. Citrullus (Java).

WILD.

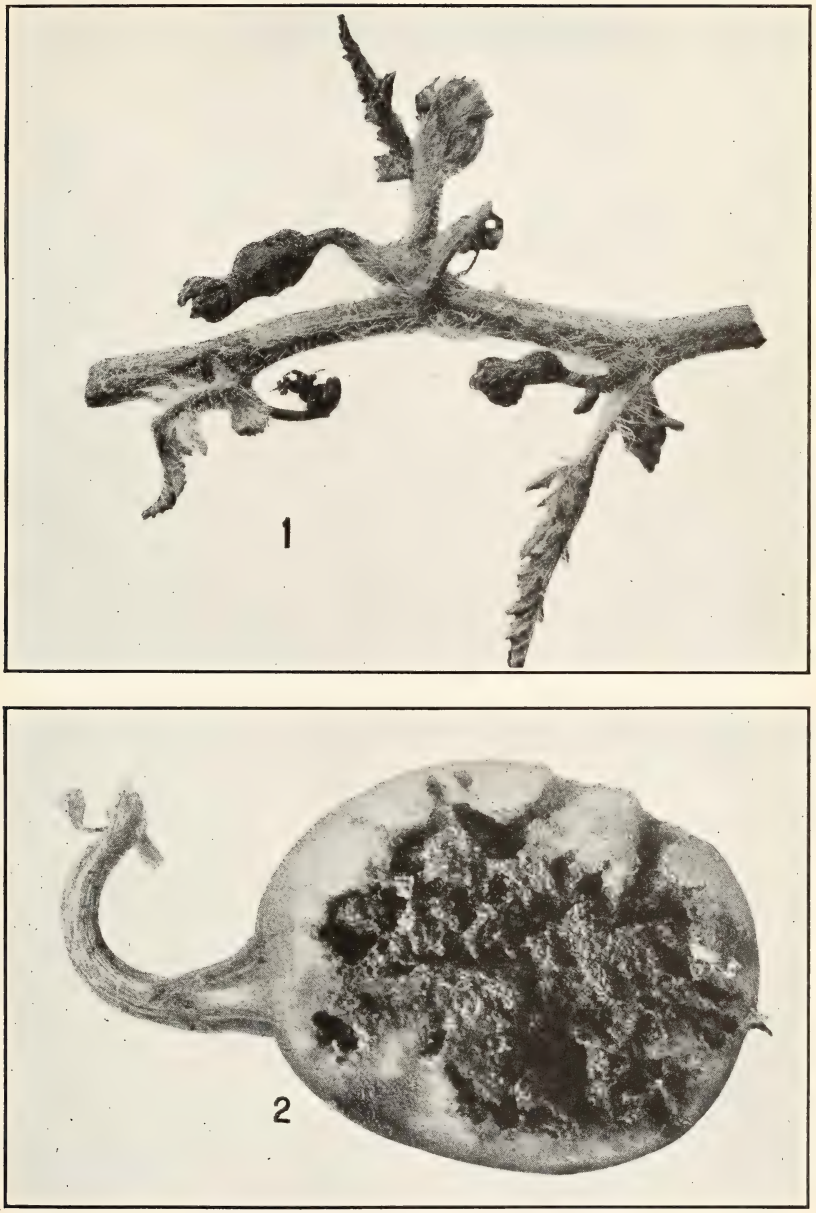
1. *Sycos* sp.
2. *Momordica* sp.

ERRONEOUSLY RECORDED HOST FRUITS.

1. Kohlrabi.
2. Cabbage.
3. Peppers.

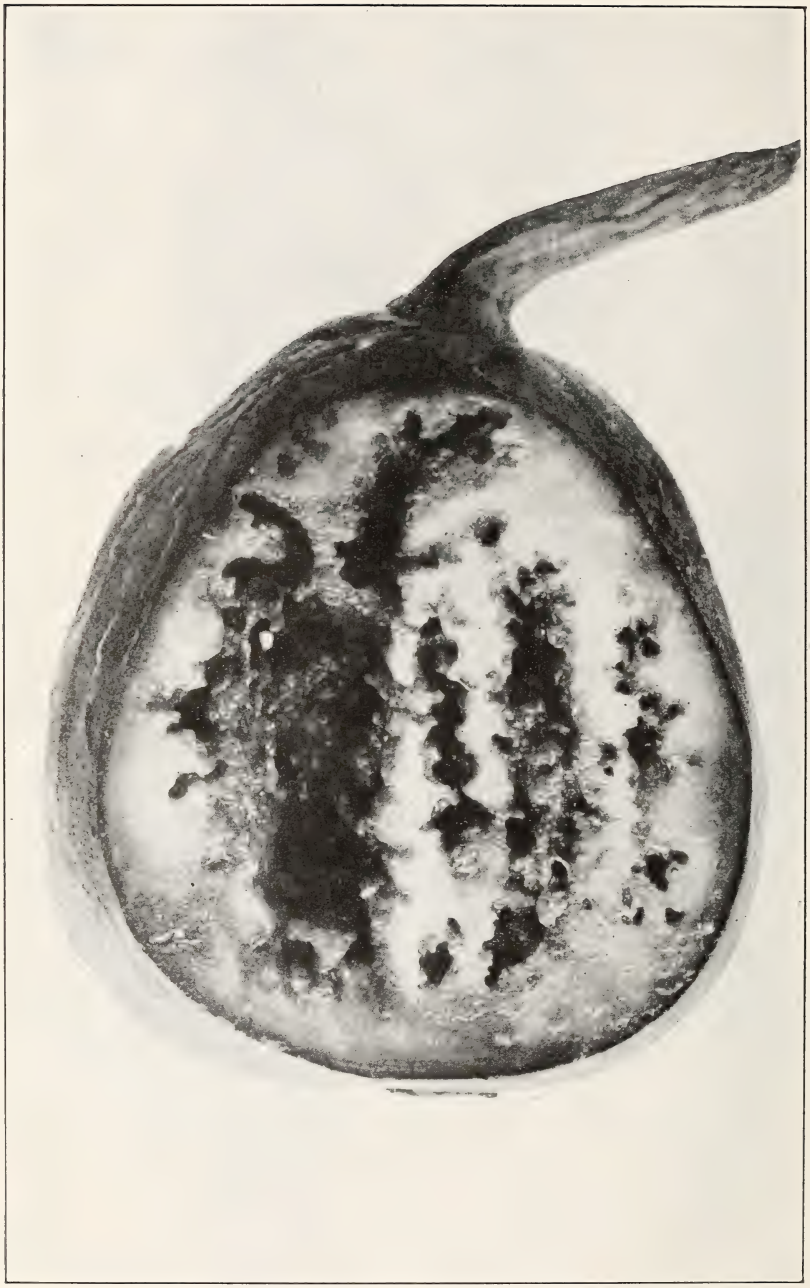
CUCURBITACEOUS PLANTS.

All the cucurbitaceous plants are subject to severe infestation, particularly of the young fruits. Cantaloupes are the most susceptible, since the vines as well as the fruit are badly attacked at all stages of growth and the fruits do not appear to develop the resistance to attack found among the older watermelons, pumpkins, and squashes. The ordinary cucumber is the most resistant to



DAMAGE TO WATERMELON BY LARVÆ OF MELON FLY.

In figure 1 is shown the mummification of young watermelons before the bloom has unfolded, caused by larvæ which have already developed and left the fruit to pupate in the soil. The complete destruction of the young fruit before mummification begins is shown in figure 2. (Original.)

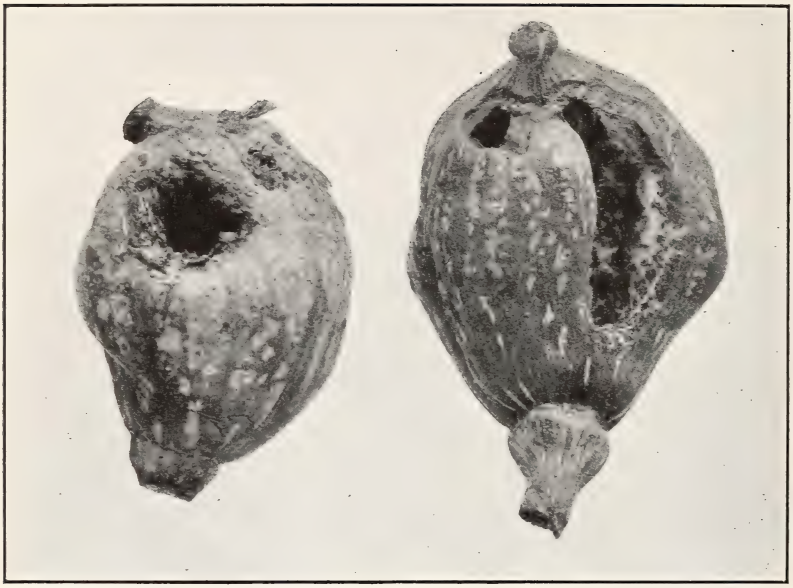


DAMAGE TO WATERMELON BY LARVÆ OF THE MELON FLY.

Longitudinal section of a young watermelon showing destruction of interior by larvæ of the melon fly. About natural size. (Original.)

DAMAGE TO WATERMELON BY LARVÆ OF MELON FLY.

Cross section of watermelon showing complete destruction of interior by the larvæ of the melon fly. Note that the larval tunnels extend through the rind in all directions and that the edible portion has been completely broken down. (Original.)

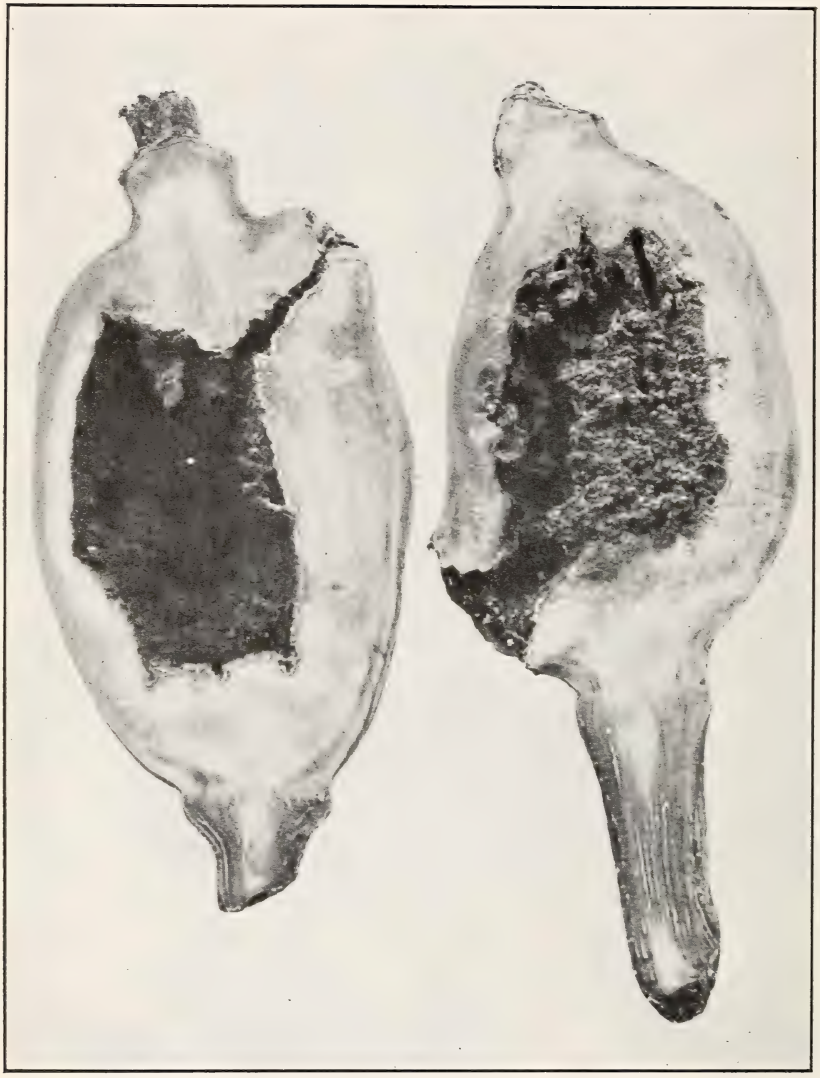


DEFORMED PUMPKIN FRUITS CAUSED BY LARVÆ OF THE MELON FLY.

Various deformities of very young pumpkins caused by infestation started before or just after fertilization of the ovary. These fruits persist for a time, due to callouses developing about points of attack, but they never reach a much larger size and are ultimately destroyed by fungi and secondary insect attack. (Original.)

WORK OF LARVÆ OF MELON FLY IN YOUNG PUMPKINS.

Cross section of young pumpkin. Each affected area represents the location of a colony of larvæ of the melon fly. (Original.)

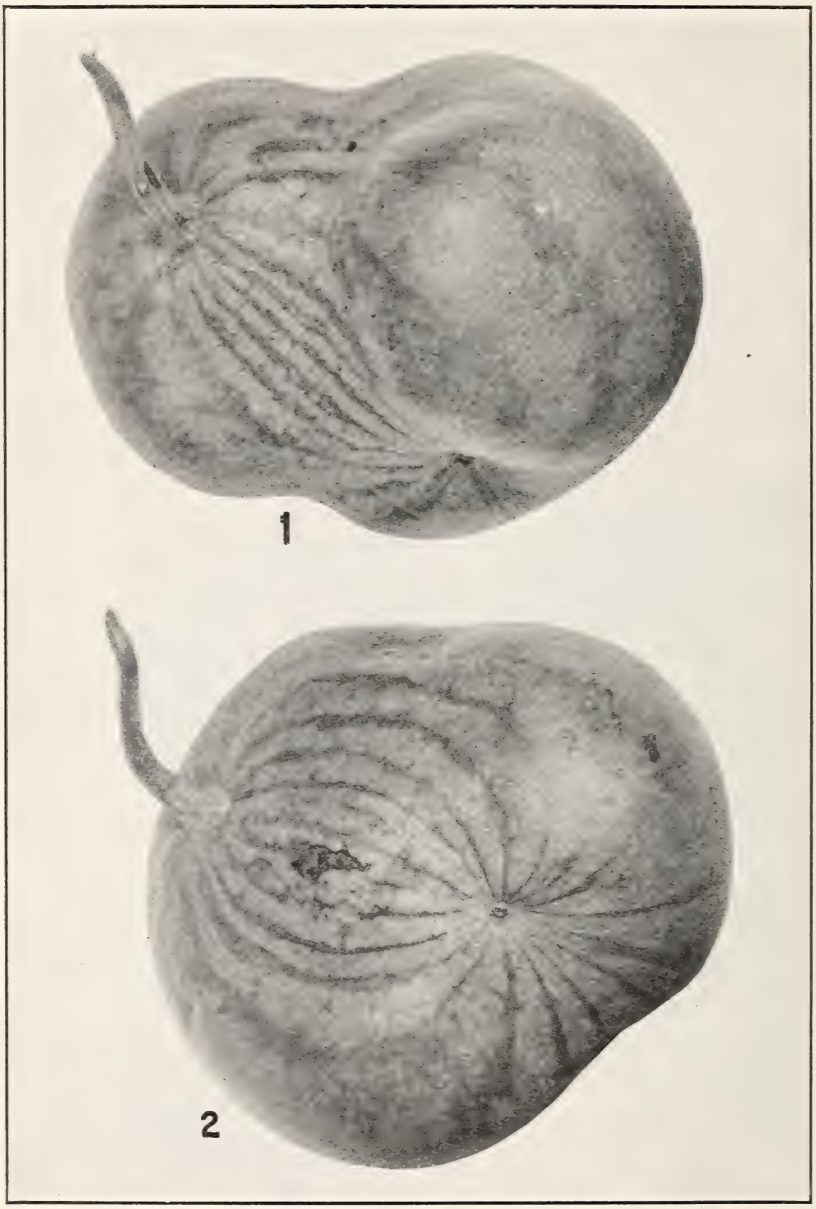


WORK OF LARVÆ OF MELON FLY IN YOUNG PUMPKIN.

Cross section of two young pumpkin fruits. In these the larvæ of the melon fly have reached full growth, and have left by the only opening to the exterior, which is also, in both instances shown, the point of original infestation. (Original.)

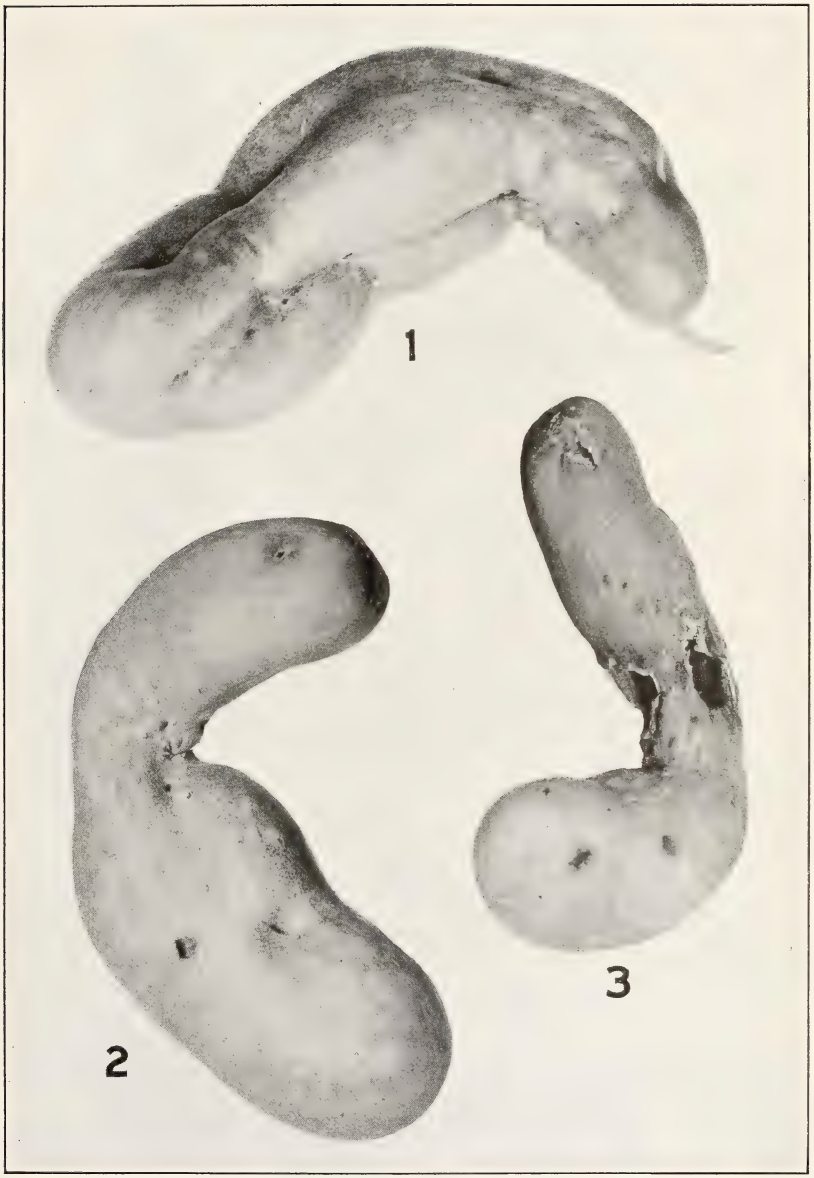
WORK OF LARVÆ OF MELON FLY IN GREEN BEAN PODS.

Bean pods affected by larvæ of the melon fly. In figures 1 and 2 a portion of the pod has been removed to expose the larvæ within and their work. Figures 3 and 4 represent pods in different stages of drying out after well-grown larvæ have left them. (Original.)



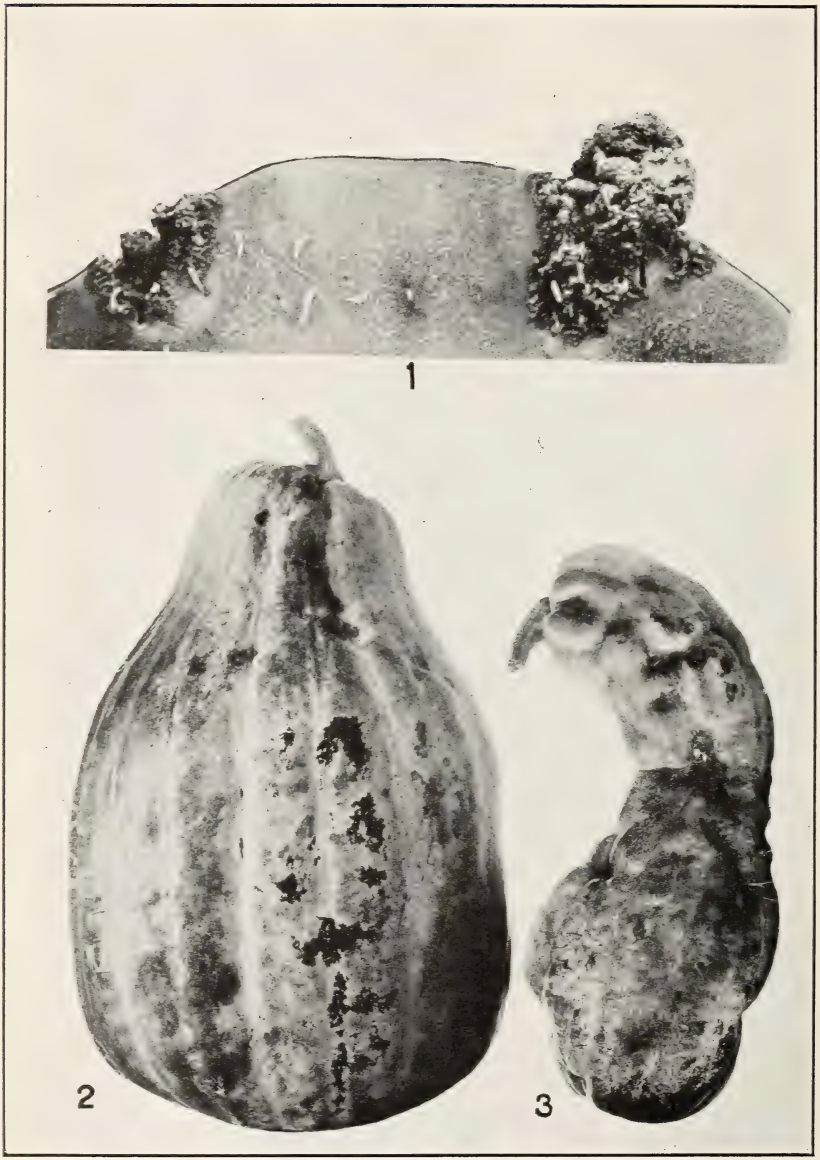
DEFORMED WATERMELONS RESULTING FROM LATE INFESTATION BY LARVÆ OF MELON FLY.

Often during the cooler months watermelons become infested so late in their development that the larvæ can not penetrate the pulp and often die within the egg chamber. The development of the fruit about these affected areas is arrested and various deformities result, as shown in figures 1 and 2. (Original.)



DAMAGE TO CUCUMBERS BY LARVÆ OF MELON FLY.

Cucumbers affected by melon-fly attack seldom become infested until after the bloom has withered. Nearly all fruits offered for sale in Honolulu markets show various deformities or imperfections caused by oviposition. Frequently fruits maintaining a firm exterior appearance are badly infested within, as were those of figures 1 and 2. (Original.)



DAMAGE TO SQUASHES BY LARVÆ OF MELON FLY.

As pumpkins and squashes become well grown they are not subject to as great infestation as when they are newly set. The female flies persist in ovipositing in any abrasions in the rind and in older punctures. The larvæ hatching are not able to penetrate the pulp to any great extent, but develop in small ulcerlike spots in the outer portion of the fruit, from which they push the developing decay, as shown in figure 1. While this infestation does not cause complete destruction, it seriously affects the symmetrical development about the affected areas. Figure 2 represents a squash slightly affected, while figure 3 represents one very badly affected although still fit for consumption. (Original.)

attack when very young, although one rarely sees fruit offered for sale in Honolulu that does not show some evidence of attack even when very carefully selected. Cantaloupes and cucumbers may be successfully oviposited in by the female fly up to the time they are ready for market. While cantaloupe growing has been practically abandoned in Hawaii since the advent of the melon fly, cucumbers are grown without protection of any sort. Although practically all fruits reaching a size fit for salad use show evidences of attack at one or more spots, the percentage of fruits rendered unmarketable is not large enough to force the oriental growers to cover the young fruits, although it would appear disastrously large to American market gardeners, who place a high value on their time. During midwinter 150 out of 153 cucumbers ready for the market at Moiliili were found variously infested.

All cucurbits grow with such rapidity in Hawaii that the oriental is willing to permit the pest to destroy fully 50 per cent of the fruits rather than go to the expense of covering each fruit as soon as or before it sets. All other cucurbits except cucumbers must be covered before or just after blooming to prevent wholesale injury. Aside from the fact that the seedlings and vines of all cucurbits except cantaloupe and watermelon are but slightly attacked, there is little difference in the susceptibility to attack of the young fruits under Hawaiian conditions. Inasmuch as the fly has been permitted to increase unchecked since its introduction, it has become so abundant that slight differences in inherent resistance to attack are not evident among host fruits growing in the field. The infestation is excessive in all unprotected fruits. If by chance pumpkins, squashes, and watermelons escape infestation until they are from 4 to 6 inches in diameter they may reach maturity, although before they reach maturity pumpkins and squashes may support numerous colonies of larvæ in open-surface wounds (Pl. XX, fig. 1), and become badly deformed. Out of 254 nearly full-grown pumpkins growing at Kahuku, 250 were found variously deformed by H. F. Willard on March 21, 1915. As many as 650 adults have been reared from a pumpkin no more than 4 inches long; the staminate bloom while still a bud may support as many as 37 well-grown larvæ.

TOMATOES.

Tomatoes are very susceptible to attack. All tomatoes offered for sale in Honolulu are apt to be infested, as shown by the reports of the market fruit-fly inspector covering several months. Fifteen ripe and partly ripe fruits examined by H. F. Willard at Hauula on March 21, 1915, were found to contain eggs or larvæ. Such severe infestation

is so general during the warmer months that data are superfluous. The tomato under climatic conditions less favorable for the increase of the melon fly would probably be found to be less susceptible to attack than cucurbitaceous crops. The fruits of the currant tomato (*Solanum pimpinellifolium*), the grape tomato (*S. lycopersicum*), the popolo (*S. nodiflorum*), and the spiny yellow-fruited Solanum common in Hawaii are all found growing about fields of cucurbitaceous crops, but the writers have never yet found them infested. During January and February the writers have seen fields of tomatoes producing a large percentage of sound fruits. Only the fruits of the tomato are subject to attack.

STRING BEANS.

The ordinary varieties of string beans grown on the mainland are not as a rule infested by the melon fly. Three hundred and seventy-five pods sufficiently ripe to have turned color, of the variety commonly known as the yellow wax bean, were examined at Haleiwa in March and were found free from attack, although growing close to a field of badly affected pumpkins. Examinations of string beans in other localities, particularly about Honolulu, indicate that only seldom are any of the varieties affected except the more fleshy, long-podded Chinese variety. This variety may be very badly attacked when grown near other favored host fruits or on land recently cleared of such crops. (See Pl. XVII.) As many as 36 well-grown larvæ have been found within a single pod.

Although the Chinese variety is the only one at times generally and badly affected, beans of all varieties except the lima bean should be included in quarantine lists. The lima bean has never been found infested. Only the pods of beans are usually affected. The larvæ prefer to feed upon the fleshy portions of the pod, but sometimes attack the seeds. In badly infested pods, attacked before the seeds are well grown, the larvæ may eat out the seeds, leaving the outer portion untouched. This is also true of cowpeas.

COWPEAS.

Although cowpeas are not grown to any extent in Hawaii, they are subject to melon-fly attack. Only the pods are affected. The writers have removed as many as 37 larvæ from a single pod. When infestation occurs early the young seeds may be devoured, but attack is more often centered upon the pod itself. There is a distinct varietal difference in the susceptibility of cowpeas. Upon this notes were made, but unfortunately have been lost.

EGGPLANT.

Froggatt (26) in 1909 reports that he and F. H. Howlett reared the melon fly from maggot-infested melons, cucumbers, bitter gourds, and eggplant. Maxwell-Lefroy (18) in 1907 and Fletcher (43) in 1914 do not mention the eggplant among the host plants of the melon fly. Fullaway (44) in 1913 lists the eggplant among garden crops affected by the melon fly, and Severin (45) in 1914 gives data on the length of the egg and larval stages in eggplant and lists this plant as a host, although he does not state that he found it normally infested in the field. Experimental work was undertaken to determine to what extent, if any, infestation occurs in the field and under forced conditions in the laboratory. Sound well-grown fruits were placed in jars containing females which had been ovipositing regularly in tomatoes. No eggs were laid in these fruits. One fruit containing a soft, slightly decayed spot on one side was similarly placed with ovipositing females for one day. Eggs were deposited in the decayed area only and later 9 flies emerged. A muskmelon allowed to hang in a jar containing females for an hour would have produced several hundred or more flies.

One hundred and fifteen fruits of all ages taken April 26 to 30, 1914, from a field at Moiliili showed no evidence of infestation when on May 2 to 5 they were examined by removing the skin for the detection of egg punctures and larval chambers. Ten fruits picked at Mokuleia on April 18, 1914, from the midst of badly infested private gardens, showed no infestation when held individually over sand in glass jars. One thousand fruits of all sizes and conditions of ripeness and soundness were examined by the junior writer during November, 1915, by carefully removing the skin of each fruit and examining with a lens all decayed spots. No melon-fly larvæ were found, although in one fruit directly beneath the skin were found several well-grown larvæ of the Mediterranean fruit fly. The senior writer has personally examined superficially during a three-year period many thousand eggplants in the fields of Moiliili, Waikiki, and Waialua districts, Oahu, without once detecting indications of attack. All fruits individually examined by the removal of skin were taken from the midst of badly infested areas where pumpkins and tomatoes could not be grown successfully because of the severity of attack.

WATER LEMONS (PASSIFLORA).

The fruit of the water lemon (*Passiflora laurifolia*) is found on the Hawaiian markets in season and is not as a rule infested by the melon fly. The writer has never seen infested fruits on the market

or on vines growing wild in the mountains. In one instance the partially mature fruits on a vine growing on a private residence in Manoa Valley were badly attacked. While the deposition of eggs in the partially-grown fruits had produced noticeable deformities in shape and cracks in the rind, a few adults were reared from but one fruit. Fully mature fruit exposed on the market is free from attack, as demonstrated by hanging fruits in jars of melon flies. The flies could not puncture the tough hardened rind. Other species of Passiflora occurring about Honolulu (*quadrangularis*, *edulis*, *alata*, and *foetida*) have never been observed infested.

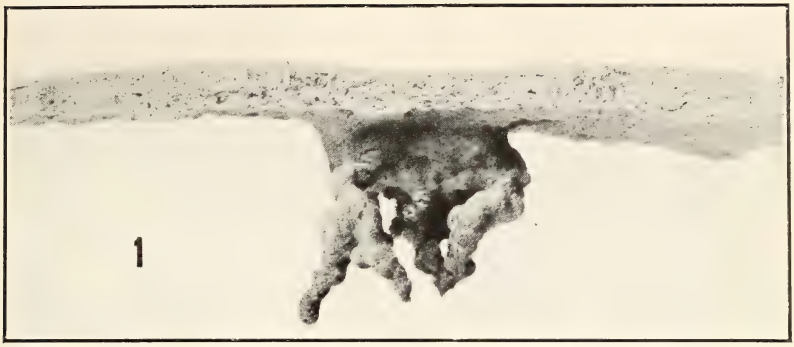
ORANGE, MANGO, FIG, PAPAYA, PEACH, AND APPLE.

These fruits have never been known to serve regularly as hosts of the melon fly. O. H. Swezy reared adults from figs growing at Kaimuki. E. M. Ehrhorn (29) reared a single female from a sweet orange from the same place. F. W. Terry reared adults from ripe mangoes in August, 1907. Van Dine (19) reports the papaya as a host fruit in 1907. The writers reared a single fly from peaches in 1914. These records of infestation must be considered as exceptional. Of the many thousand peaches and numerous figs, oranges, mangoes, papayas, and other fruits which normally serve as host for the Mediterranean fruit fly that the writers have used to obtain fruit-fly material, none, except the single peach referred to above, have yielded melon flies.

It seems probable that the melon fly will oviposit rarely in these fruits. Larvæ hatching from eggs deposited by females in confinement in apples succeeded in the fruits of softer texture in reaching maturity. Others hatching in apples of firmer texture failed to penetrate the pulp, but crawled out through the puncture opening and died close by it on the surface of the fruit.

CABBAGE AND KOHLRABI.

Fullaway stated (47) in 1915 that the melon fly had often been reported infesting the heart of cabbage, but that the infestation was not at all common and is considered to be due to abnormal conditions in the plants and of a secondary nature. In 1913 the same writer records cabbage as a host plant. No other writers have reported melon-fly infestations of cabbage. The writers have examined cabbages without discovering melon-fly larvæ. They have frequently found larvæ closely resembling those of the melon fly and from them have reared *Acritochaeta pulvinata* Grims. The larvæ of this fly are found very generally in decaying vegetable matter about gardens in Hawaii. The writers have on several occasions removed them from beneath the sound leaves of cabbage heads, whence they

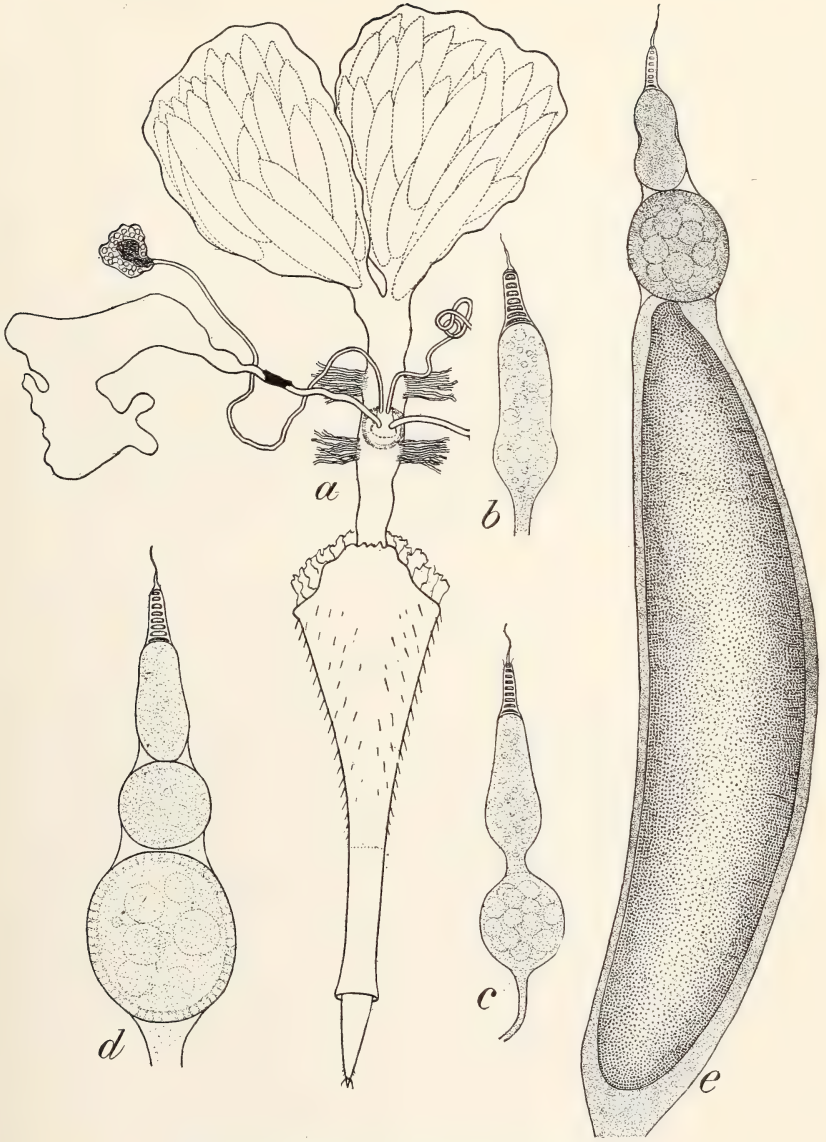


TYPES OF DAMAGE BY LARVÆ OF MELON FLY.

FIG. 1.—Gall-like development formed about the eggs or very young larvæ within a pumpkin. FIG. 2.—Cross section of the wild host *Sycos* sp., showing destruction caused by larvæ. FIG. 3.—Seedling watermelon showing runner killed back by burrowing larvæ. (Original.)

WILD HOST PLANTS OF THE MEDITERRANEAN FRUIT FLY (CERATITIS CAPITATA) AND OF THE MELON FLY (BACTROCERA CUCURBITAE).

The cactus (Opuntia) and Chinese cucumber (Momordica) grow wild in pasture lands on the Island of Hawaii, the one furnishing food for the Mediterranean fruit fly and the other for the melon fly. In these two hosts these flies are capable of subsisting in areas unfit for cultivation. (Original.)



REPRODUCTIVE SYSTEM OF THE FEMALE MELON FLY.

Reproductive system of the adult female melon fly: *a*, System as a whole; *b*, egg tube from ovary of newly emerged female; *c*, same as *b*, 23 days after emergence (January) of adult; *d*, same as *b*, 33 days after emergence (January–February) of adult; *e*, egg tube containing) mature egg ready to be fertilized. Highly magnified. (Original.)

PROTECTING CUCURBITS FROM ATTACK BY MELON FLIES.

Figures 1 and 2 illustrate one of the methods employed by Oriental market gardeners to protect developing cucurbits from melon-fly attack. Each fruit (in this case of *Momordica* sp.) is placed, immediately after it has been fertilized, within a long envelope made of newspaper. (Original.)

had evidently retreated when the outer decayed leaves were disturbed.

Kohlrabi has been reported infested by Severin[1] (45). The writers have never found larvæ attacking this plant, and because of the frequency with which the larvæ of *Acritochaeta pulvinata* are found in decaying portions, as in cabbage, the writers believe that cabbage and kohlrabi have been erroneously recorded as host plants.

PEPPERS.

Fullaway (44) in 1913 is responsible for the only record of peppers as a host fruit for the melon fly, although he does not state the nature of the infestation. Larvæ of *Acritochaeta pulvinata* and of the Mediterranean fruit fly are found in bell peppers. The careful examination of 1,000 bell peppers grown at Waikiki close by badly infested tomatoes and cucumbers during November, 1915, showed infestation only by the Mediterranean fruit fly. A like number of fruits gathered from the same locality during August, 1914, and placed over sand in jars produced no evidence of infestation by the melon fly.

WILD FOOD PLANTS.

The two species of cucurbits, *Sycos* sp. and Chinese cucumber (*Momordica* sp.), are the only host fruits that can be considered wild in Hawaii. The Momordica beyond question has recently escaped cultivation. The fruits of both are readily susceptible to melon-fly attack. Fortunately *Sycos* sp. (Pl. XXI, fig. 2) is not abundant and the Momordica (Pl. XXII) is limited in its distribution although spreading fast.

The writers have found fruits of the Sycos infested on the windward side of Oahu and in the Kona district of Hawaii. The Momordica has escaped cultivation in many places in Hawaii and wherever present is found infested. On the island of Hawaii, in the Kona district, from sea level to about 1,500 feet, its vines have formed dense growths over the stone walls and bushes and have even killed out large patches of grass. Its fruits are more susceptible to attack than those of Sycos, but both host fruits, especially in Kona, furnish with their fruits ripening at all seasons a continuing supply of food upon which the melon-fly larvæ can feed, whether or not cultivated host fruits are grown in their neighborhood. From Momordica vines covering a patch of pasture land 6 feet square, 331 fruits were gathered during November, 1914, of which only 12 had not been infested.

[1] Severin states in correspondence that he certainly reared the melon fly from kohlrabi and eggplant under field conditions.

These fruits, which were of all sizes up to 1½ inches in diameter, averaged between three and four punctures per fruit, with a maximum of 15 punctures on the more exposed fruits. From 7 feet of stone wall 442 fruits were gathered, and of these 193 were so badly affected that they had dried up without developing seeds, and only 11 were not affected. From 250 fruits placed over sand 1,586 larvæ, or an average of 6.5 larvæ per fruit, were reared.

LIFE HISTORY AND HABITS.

METHOD OF STUDY.

As adults die in greatest numbers within 48 to 72 hours after emergence if food is not given them, those required for future observation must be transferred to a place where they may be fed and cared for daily. In this work the writers have found glass jars 9 by 12½ inches covered with cheesecloth very convenient. Such jars will hold from 100 to 200 flies in good condition. Fruit juices of almost any sort are eagerly eaten. Water slightly sweetened with pineapple (*Ananas ananas*) sirup was used with good results but was replaced later by a mixture of water and finely divided parts of papaya (*Carica papaya*). When fed on such diluted food adults thrive best on two feedings a day, one in the morning and one late in the afternoon. The food may be applied in finely divided drops to the sides of the jar by flirting the mixture forcibly against the cheesecloth covering by means of a snapping movement of the thumb and forefinger. The adults feed greedily and soon become distended. In this condition many fall and rest upon the bottom of the jar; hence, the less food falling on this portion of the jar the fewer will be the deaths resulting from entanglement in it. Feeding by flirting mixtures through the cloth covering causes the sides of the jars to become soiled quickly and necessitates the changing of adults to clean jars every two or three days.

Eggs may be easily secured by suspending host fruits within the jars containing sexually mature adults. Breaks made in the epidermis of the host fruit with any sharp object often insure the deposition of eggs in the portion of the fruit desired. By timing the exposure of fruits with adults, eggs of definite age can be secured; and if these are immediately dissected from the fruits, arranged on a green leaf, and placed over a plug of wet cotton in a vial inverted in water the embryonic development and hatching may be observed under normal conditions of heat and moisture. In obtaining detailed data on larval development single larvæ upon hatching may be placed in small squares of ripe papaya pulp and transferred twice daily to fresh squares. Pupæ of known age can be obtained easily by placing infested host fruits over sand and sifting the sand at stated frequent

intervals for the larvæ and puparia. The labor of sifting is made easier if the fruits are placed on a wire mesh which holds them away from the sand.

THE ADULT.

DESCRIPTION.

The adult of the melon fly is larger than related species of Bactrocera, being under normal conditions from 6 to 8 mm. in length. According to Bezzi (36) it may be distinguished from all other Indian species by the fact that it has the posterior cross-vein widely bordered with brown. The original description by Coquillett (2), which is good, is given in full in the bibliography (p. 58), together with the supplementary notes made by Bezzi (36), and to those descriptions the investigator should refer for details. In general the arrangements of the black spots upon the yellowish head, the light yellow markings upon the reddish-yellow thorax, and the brown spots upon the otherwise hyaline wings make the identification of the melon fly an easy matter. As a further aid to identification figure 1 and Plate II have been added.

EMERGENCE.

Adults emerge during the early morning hours in warm weather, but during cooler weather more scatteringly throughout the day. In common with all Cyclorrhapha, the adult makes use of the ptilinum in breaking the walls of the puparium and in forcing its way to the surface of the soil, or in extricating itself from other confining walls. Just after emergence, before the normal colors of the body have developed and while the chitin is still flexible, the adults are able to push their way through incredibly small openings, being able so to flatten their bodies that they can make use of small cracks in soil from which they could not otherwise escape, and can extricate themselves from containing fruit boxes and many other containers not absolutely tight. Cracks of the thickness of ordinary blotting paper do not always prevent their escape just after emergence.

LONGEVITY OF ADULT MELON FLIES.

With food.—The data included in Table I are the first that have been made to determine the age to which adult melon flies can live if kept well supplied with food. One female lived from February 17, 1914, to April 4, 1915, or 13 months and 15 days, a total of 431 days. One female emerging at the same time, but not included in Table I, lived until April 3, 1915. In general, the adult melon fly appears to be very hardy and far more resistant to moisture in rearing jars than is the adult of the Mediterranean fruit fly. This may be due principally to the larger and more robust build of the melon fly. The data in Table I, covering the 9½ months after the flies had reached the age of 4 months, show that the death rate is low among the older flies. Two other lots of adults of 43 (15 males and 28 females) and 44 (15 males and 29 females) individuals of the same age and simi-

larly cared for, and upon which like data were secured, died at practically the same rate as the flies recorded in Table I.

Of any lot of adults kept in confinement for experimental purposes fully 30 per cent may be expected to die within the first 2 to 4 weeks of life, even when given the best of care and kept in jars not overcrowded. Two adults emerging on August 28, 1913, died on October 29 and November 2, respectively. Of 15 flies issuing August 26, 1913, one lived until November 27, but the others were dead by October 20. Other data might be included, but they would bring out no facts to disprove that the length of adult life is variable under like conditions. The chief interest centers about the fact that certain adults may live long periods and thus keep the pest alive during seasons when host fruits are not in condition for oviposition.

TABLE I.—*Longevity of adult melon flies emerging on Feb. 17, 1914.*[1]

Date of observation.	Number of flies alive.		Number of flies dead.		Date of observation.	Number of flies alive.		Number of flies dead.		Number of eggs deposited on sides of jar.[2]
	Male.	Female.	Male.	Female.		Male.	Female.	Male.	Female.	
June 17	21	23	.....	.....	Dec. 17	8	14	.....	1	12
27	21	23	.....	.....	22	8	14	.....	.....	54
29	20	23	1	.....	26	4	11	4	3	56
July 7	20	23	.....	.....	29	4	10	.....	1	35
10	20	22	.....	1	Jan. 2	4	10	.....	.....	21
13	19	22	1	.....	5	4	10	.....	.....	14
16	19	22	.....	.....	8	4	10	.....	.....	6
Aug. 1	19	22	.....	.....	12	4	10	.....	.....	26
3	18	22	1	.....	15	4	9	.....	1	20
6	18	22	.....	.....	20	4	9	.....	.....	58
8	18	21	.....	1	25	4	9	.....	.....	62
19	18	21	.....	.....	29	4	9	.....	.....	17
22	17	20	1	1	Feb. 1	3	9	1	.....	36
24	17	20	.....	.....	4	3	8	.....	1	14
27	16	20	1	.....	10	2	7	1	1	.....
29	16	20	.....	.....	23	1	7	1	.....	33
Sept. 12	16	19	.....	1	25	1	6	.....	1	11
14	14	17	2	2	27	1	6	.....	.....	37
Oct. 16	13	17	1	.....	Mar. 5	1	5	.....	1	.....
21	13	17	.....	.....	11	1	3	.....	2	.....
27	13	16	.....	1	22	0	3	1	.....	11
Nov. 7	12	16	1	.....	25	.....	2	.....	1	11
11	9	16	3	.....	29	.....	1	.....	1	.....
17	8	16	1	.....	31	.....	1	.....	.....	.....
25	8	15	.....	1	Apr. 3	.....	1	.....	.....	.....
Dec. 2	8	15	.....	.....	4	.....	0	.....	1	.....

[1] Mortality records were not started until June 17, or not until the flies were 4 months old.
[2] No record of eggs deposited on sides of containing jars were started until December 17, or not until the flies were 10 months old. Compare data with data on daily rate of oviposition.

Without food.—Adult melon flies die rapidly within a few days if not given an opportunity to feed. This is shown by the records of mortality of flies placed in clean glass jars and given no food or water, but kept otherwise under conditions identical to those under which flies regularly fed are kept. No flies in the following experiments lived for more than 100 to 102 hours without food and water, or for

more than 120 hours without food but with water. Flies that had been regularly fed for over 6 months did not live longer when deprived of food than those kept without food from emergence. The rate of mortality among six lots of adults was as follows:

(1) Twenty-five adults, emerging on January 3 and fed daily on papaya and water until 9 a. m., January 17, were placed in a clean jar immediately after feeding. Thereafter they were given only water three times daily. One died between 4 p. m., January 17, and 9 a. m., January 18; 1 between 2 and 3 p. m., January 19, 2 between 4 p. m., January 19, and 9 a. m., January 20; 13 between 4 p. m., January 20, and 8 a. m., January 21; 1 between 11 a. m. and 12 m., January 21; and 3 between 4 p. m., January 21, and 9 a. m., January 22.

(2) Fifteen adults, which emerged June 22, 1915, and fed until December 13, 1915, were placed at 9 a. m. of the latter date, immediately after being fed, in a clean glass jar. All were dead by 8 a. m., December 17. Three died between 1 and 4 p. m., December 14; 6 between 4 p. m., December 14, and 4 p. m., December 15; 3 between 4 p. m., December 15, and 8 a. m., December 16; 3 between 4 p. m., December 16, and 8 a. m., December 17.

(3) Thirteen adults, emerging about 8 a. m., December 26, 1915, were placed in a glass jar. These flies had no opportunity to feed after emerging. Two died between 4 p. m., December 27, and 8 a. m., December 28; 8 between 4 p. m., December 28, and 8 a. m., December 29; and 3 between 1 and 3 p. m., December 29.

(4) Sixty-six adults, emerging about 9 a. m., December 30, 1915, were placed, without having been fed, in a clean jar. Ten died between 9 p. m., December 31, and 8 a. m., January 1, 1916; 28 between 9 a. m., January 1, and 8 a. m., January 2; 3 between 3 and 6 p. m., January 2; 5 between 9 p. m., January 2, and 6 a. m., January 3; and 1 between 1 and 3 p. m., January 3.

(5) One hundred and forty-nine adults, emerging about 9 a. m., December 31, 1915, were placed, without having been fed, in a clean jar. Ten died between 3 and 6 p. m., January 1, 1916; 19 between 9 p. m., January 1, and 8 a. m., January 2; 56 between 3 and 6 p. m., January 2; 47 between 9 p. m., January 2, and 6 a. m., January 3; 11 between 1 and 3 p. m., January 3; 5 between 4 p. m., January 3, and 8 a. m., January 4; and 1 between 8 a. m. and 12 m., January 4.

(6) Sixty-eight adults, emerging about 9 a. m., December 28, 1915, were placed, without having been fed, in a clean glass jar. Two died between 4 p. m., December 29, and 8 a. m., December 30; 8 between 1 and 4 p. m., December 30; 57 between 4 p. m., December 30, and 8 a. m., December 31; and 11 between 1 and 3 p. m., December 31.

FOOD OF ADULTS.

The food of the adult melon fly consists of plant juices, honeydew, nectar, or even the juices of dead insects. In confinement the flies may be seen occasionally feeding upon specimens which have died, although this does not appear to be a universal habit. Severin (45) has observed one adult feeding upon a dead and partly decomposed caterpillar. The observations of the writers would indicate that adults obtain the larger portion of their food from honeydew, and especially from the juices exuding from the injured portions of their hosts. Adults are found in large numbers on foliage covered with the exudations of honeydew, no matter whether it is formed by the

cane leafhopper (*Perkinsiella saccharicida* Kirkaldy) on sugar cane, by the green scale (*Coccus viridis* Green) on coffee leaves and fruit, by the corn leafhopper (*Peregrinus maidis* Ashm.) on corn tassels and leaves, by the bean aphis (*Aphis gossypii* Glover) on different varieties of beans, or by the banana aphis on banana foliage and flowers. Wherever honeydew is present the melon fly is among the many insects attracted.

The adults are particularly fond of the juices exuding from the ruptures made by the female in the epidermis of the host while forming the cavity in which to deposit eggs. Cucurbits in general exude considerable juice when injured, and this is eagerly eaten by both sexes of adults. Fruits broken in the field, crushed vines, and even the decayed areas in infested fruits are attractive to adults. Although adults have seldom been observed to visit the flowers of cucurbits in search of food, they have been observed, apparently feeding, among the flowers of *Acacia farnesiana* Willd., the banana (*Musa* spp.), and sunflower (*Helianthus* sp.). On numerous occasions they have been seen drinking small droplets of moisture during the early morning or after light showers.

In the laboratory, in confining jars, the adults have been kept alive by feeding with several fruit juices, but they thrived best upon papaya pulp passed through cheesecloth and then diluted with about twice its bulk of water.

Of special interest is the attraction of the flowers of the orchid, *Phalaenopsis schilleriana* Reichb. f. Mr. W. M. Giffard, of Honolulu, first observed adults feeding upon the nectar of this orchid during April, 1913. Dr. H. L. Lyon and Mr. Albert Waterhouse, also of Honolulu, have observed many adults about their greenhouses, into which they had been lured by the orchid flowers. One florist feared that the adult melon fly might injure the blooms, but experiments and observation proved that they were only after the nectar.

PROPORTION OF SEXES.

The sexes are quite evenly divided. The examination of 1,049 individuals emerging from 8 lots of fruit showed 524 to be males and 525 to be females. The proportion of sexes of each of the eight lots is as follows:

Males	25	20	73	70	83	44	102	107
Females	24	37	65	60	70	45	123	101

MATING.

So far as the writers have been able to detect, neither sex of the melon-fly adults gives off an odor.

Inasmuch as adults of the Mediterranean fruit fly show at all times during the day, particularly during the warmer months, indications

of sexual activities within three or four days after emergence, and begin ovipositing soon thereafter, the writers were at loss to explain the apparent indifference to each other of the sexes of the melon fly. It was thought for a time that failure to secure evidence of sexual activity might be due to improper confinement or feeding, and a number of lots of adults were discarded before it was discovered that melon flies mate only at dusk and only after they have become somewhat older than adults of *Ceratitis capitata.*

Recent feeding experiments with the melon fly have shown that certain foods may play an exceedingly important part in the stimulation of bodily forces, sexual activity, and egg maturation. These experiments have shown that the use of fresh cucumbers, cut open and kept constantly in the jars containing the adults, would so accelerate the development of the reproductive system that copulation commenced as early as ten days after emergence from the pupal stage. Thus, in four lots of flies emerging on October 24, 27, 28, and 29, 1916, comprising a total of 1,230 adults, mating commenced with a few individuals in each lot, successively, at sunset, the tenth day after emergence, the mean average temperature being 76.4° F. and the mean relative humidity 69.1 per cent. This is a most striking condition when comparison is made with the ages at time of first mating of adults that are confined in jars of similar size, but fed on papaya and water or sugar and water. Many hundreds of adults kept in confinement during the years 1913, 1914, and 1915 in Honolulu and fed on papaya and water were never seen to mate before 20 days after emergence. Thus, out of about 200 individuals emerging on May 24, 1914, which were fed on papaya and water one pair was noted in coition for the first time on June 13, or 20 days after emergence. Among a second lot of adults, emerging on May 23 and similarly fed, no adults mated until June 16, when two pairs were seen mating. The majority of females in these lots did not mate until they were fully 25 days old. The daily mean temperature for the period from May 23 to June 16 averaged 75.5° F., while the mean relative humidity averaged 69.3 per cent. Individuals of another lot of flies emerging January 3, 1916, and fed on papaya and water showed no indications of mating until early in February. The lower average mean temperature of 71° F., and the higher mean relative humidity of 78.5 per cent of January, were responsible for the greater period required for the beginning of sexual activity.

Evidences of sexual activity begin during the warmer months only at about sunset. From sunset until darkness the sexes are in a state of intense activity. Both sexes dart rapidly about the containing jar and in their efforts to copulate produce much confusion. Pairs remain in coitu, in some instances, until daybreak. Females mate frequently and with different males.

OVIPOSITION.

Age when oviposition begins.—The age at which oviposition begins has never been determined broadly until the present investigation. Information on this point is of importance, as the adult appears to be the most vulnerable point in the life cycle of this pest from the standpoint of artificial control. Severin, who first undertook to solve this problem, states (45) that "a large number of adults upon emerging were kept in breeding jars and fed on diluted molasses, fruit and vegetable juices, and water. After having been kept in captivity for 8 days 3 females were dissected, but no fully developed eggs were found in the ovaries. A daily dissection of 3 fruit flies was continued from now on, and at the end of 14 days 23 ripe eggs were counted in the two ovaries of one fly, but others did not show mature eggs in the ovaries at the end of 16 days. At the end of 17 days 31 eggs were dissected from the ovaries of another specimen. In all probability the effect of confining the insects in breeding jars plays an important part in the rate of development of the eggs." These dissections, Severin concludes, indicate that egg-laying begins 14 to 17 days after the adults emerge.

As noted under the subject of "Mating," varying types of food supplied adults in captivity may have widely varying effects upon the development of the eggs. Thus, four lots of adults emerging on October 24, 27, 28, and 29, 1916, comprising a total of 1,230 flies, which had constant access to the juice of fresh cucumbers cut open, began ovipositing in 12, 11, 11, and 11 days, respectively, each lot depositing from 17 to 29 eggs the first day. The mean average temperature during this experiment was 76.4° F. and the mean relative humidity 69.1 per cent. When fed upon papaya and water a most surprising difference results in the rapidity of egg development. The experiment was repeated many times during the years 1913, 1914, and 1915 and many hundreds of adults were used. Thus with a mean temperature averaging 75.5° F. and the mean relative humidity 69.3 per cent females did not begin ovipositing until about one month after eclosion. While fruit was placed in jars with about 1,000 adults which emerged from May 23 to 25, no attempts at oviposition were noted until June 23, when 12 punctures containing no eggs were made in a mango by females that emerged on May 24. The first eggs, 12 in number, were laid on June 25, or 32 days after eclosion. No eggs were obtained from females that emerged on May 25 until June 28, or 34 days after eclosion. This is remarkable when comparison is made with females that were fed on cucumbers and which began ovipositing when only 11 to 12 days old.

Adults emerging on January 3, 1916, during the coldest portion of the year at Honolulu, and fed on papaya and water when the

mean temperature for January was 71° F. during 1916 and the mean relative humidity 78.5 per cent, did not oviposit until February 17, although they were given abundant opportunity. In this instance no eggs were deposited until the females were 44 days old.

In the case of the adults emerging January 3, 1916, and fed on papaya and water, dissections were made of the ovaries of females at frequent intervals from the time of emergence until egg laying began. The appearance of the ovarian tubes dissected from females 1, 23, 33, and 38 days after emergence is shown in Plate XXIII. At no time were the ovarian tubes found to contain a well-graduated series of eggs, as is found in many insects, or as found by Dr. Illingsworth in the ovarian tubes of the apple maggot (*Rhagoletis pomonella* Walsh) and the cherry fruit fly (*Rhagoletis fausta* O. S.)

From the observations made upon the development of the eggs of melon flies fed upon the juice of cucumbers it seems reasonable to conclude that under natural conditions egg deposition commences almost as soon as the eggs have reached maturity in the egg tubes.

Whether confinement does retard egg development has been difficult to determine, but development of eggs within the ovarian tubes of the Mediterranean fruit fly progresses so rapidly in confinement under like conditions that the writers conclude that confinement of the female melon fly in large jars, with plenty of food, does not retard development.

Portion of plant selected.—The female fly deposits eggs at random in various portions of the host plants, the portion selected depending largely upon the stage of growth and variety of host. In young seedlings, particularly succulent watermelon seedlings, eggs are deposited within the crown of the plant or in the petiole of the leaf. As the cucurbits develop runners the eggs may be deposited in these, usually near the growing tip or less frequently farther back in the tougher, older portions. The older vines are seldom made use of for oviposition, and of the cucurbits, the vines of the pumpkin, squash, momordicas, and cucumbers are least attractive. No oviposition has been noted in tomato or bean stalks. The female prefers to oviposit within the unfertilized, still undeveloped ovaries of all cucurbits, with the exception of the young cucumbers, which are not attacked until the fruits are from 2 to 4 inches long. Ovipositing into the male bloom of squash and pumpkin is so universal that it would appear that this portion of the plant is as attractive to the female as the unfertilized ovaries. Oviposition has never been observed to occur in the male bloom of watermelon, cantaloupe, *Momordica* spp., or the bloom of tomatoes, cucumbers, and beans. Even after pumpkins and squashes become so well developed that the melon-fly larvæ can not penetrate and cause their destruction, the

female deposits batch after batch of eggs in the breaks in the epidermis and superficial wounds made by larvæ developing from previously deposited eggs.

Process of oviposition.—The process of oviposition may be readily seen at all seasons of the year in Hawaii. When the female has found a suitable place for oviposition the abdomen is bent at nearly right angles to the long axis of the body by drawing its tip toward the legs. Having secured a proper purchase, the ovipositor is forced into the host to depths varying to ¼ inch. The depth of the incision made by the ovipositor varies with the succulency of the host, hence the small chamber for the reception of the eggs may lie directly beneath the epidermis or fully the length of the eggs beneath it. The data included in Table II indicate that the female does not deposit more than 37 eggs at one time, although many punctures contain but one egg. The number of eggs found in any one puncture, especially where the number is large, is not indicative of the number of eggs deposited during one period of oviposition, as many females may oviposit through the same break in the epidermis, or the same female may return more than once to deposit fresh batches of eggs. This is particularly true in the case of host fruits which may offer obstacles to egg laying.

Rate of oviposition.—No data have ever been published on the daily rate of oviposition, except by the writers in their preliminary paper (46). The data included in Tables II, III, and IV record the rate of oviposition not only of individual females which, from the time they began ovipositing until they died, were kept well supplied with host fruits, but also of others which had been deprived of host fruits until they were over 9 months of age.

In Table II is recorded the rate of oviposition of 7 females which were given every opportunity to oviposit in preferred host fruits, tomatoes, throughout life. No fly deposited more than 37 eggs a day. Fly No. 1 deposited 14, 19, 13, 29, 16, 19, 16, 12, 17, 7, 9, 16, 7, 12, 37, 25, 24, 21, 28, 6, and 18 eggs, respectively, per day during the first three months (summer months) after depositing her first eggs. During the same period fly No. 3 deposited but 13, 9, 15, 10, 4, 19, 3, 18, 4, and 3 eggs, while fly No. 4 deposited 3, 10, 25, 6, 11, 11, 6, 11, 1, 3, 16, 10, 9, and 24 eggs. Fly No. 1 deposited in the winter months during the seventh, eighth, and ninth months of life 10, 2, 18, 14, 15, 20, 13, 9, and 3 eggs. Fly No. 4 deposited during the ninth and last month of life (winter month) but 3, 2, 3, 4, 1, 1, and 1 eggs.

The oviposition records of Table III were made by females given no opportunity to oviposit in host fruits until over 3 months old. Fly No. 1 deposited 21, 14, 4, 1, 10, 18, 3, 3, 16, 2, 8, 13, 13, 8, 10, 10, 12, 9, and 16 eggs, respectively, per day during the first 3 months (sum-

mer months) after having been given access to host fruits. Under like conditions fly No. 2 deposited 2, 17, 13, 12, 4, 7, 16, 14, 28, 8, 12, 17, 12, and 29 eggs, respectively, per day during the first 4 months.

Fly No. 1 of Table IV, which was not given access to host fruits until she was nearly 8 months old, deposited, as indicated, 21, 7, 13, 3, 18, 13, 10, and 2 eggs on different days during the ninth month (October-November) of her life. Fly No. 2 of Table IV, which was not given access to host fruits until she was nearly 9½ months old, deposited 6, 2, 7, 6, 3, 6, 1, 3, 12, 3, 3, 8, and 4 eggs on different days during the eleventh, twelfth, and thirteenth months of life, which also were the last 3 of life and colder than the average for December, January, and February at Honolulu.

The melon-fly female differs from the female of the Mediterranean fruit fly in that she deposits a larger number of eggs per day at greater intervals instead of a smaller number almost daily. Fly No. 4, Table II, very closely approached the habit of *Ceratitis capitata* by depositing a small number of eggs daily with great regularity from November 2 to the middle of the month. It will be noted that the flies whose records appear in Table IV averaged 10 and 6 eggs, respectively, for each day on which they oviposited, which compared quite favorably with the averages of 9.5, 13.6, and 13.5 of Table III and 14.9, 9.4, 6.3, 5.3, 10.3, 7.6, and 13.1 of Table II, especially when one considers the small number of flies under observation and the variation in egg-laying capacity shown by the larger number and very much younger flies of Table II, and the colder months of the year during which the eggs were deposited. Fly No. 1 of Table II, which deposited a total of 687 eggs, averaged but slightly over 3 eggs per day during the 227 days between the time when she deposited her first and last eggs.

TABLE II.—*Daily rate of oviposition of the melon flies that emerged on May 25 and were placed separately with fruit on June 25, 1914.*

Date of observation.[1]	Number of eggs deposited.						
	Fly No. 1.	Fly No. 2.	Fly No. 3.	Fly No. 4.	Fly No. 5.	Fly No. 6.	Fly No. 7.
1914.							
July 10						23	
11			13		17		
15	14					12	
17			9		14		
18	19						
19							19
21						6	
22	13						
23					10		
24				3			
26						23	
27	29						
29					21		
Aug. 1				10		5	
2			15				

[1] Dates on which none of the flies oviposited are omitted from the table.

TABLE II.—*Daily rate of oviposition of the melon flies that emerged on May 25 and were placed separately with fruit on June 25, 1914*—Continued.

Date of observation.	Number of eggs deposited.						
	Fly No. 1.	Fly No. 2.	Fly No. 3.	Fly No. 4.	Fly No. 5.	Fly No. 6.	Fly No. 7.
1914.							
Aug. 4		2			15		
5				25			
6	16						
7		6					
8					10	8	
9	19				3		
11				6		1	
12					2		
13					10		
14	16						23
15			10				
16						1	
17					11	2	9
18				11			
19	12					1	
23						8	
24	17	12			9		
29	7			11	5		
30	9						7
Sept. 2						2	
3		3					
4	16						
5					7		
6				6	(1)		
8	7	13					
9	12						
10						(2)	
17							12
18		5	4				
19							22
23	37	24		11			
25	25	10		1			
26		13	19				22
27	24						
Oct. 2		6	3	3			26
7	21	(3)	18	16			12
9	28			10			
10	6		4	9			7
12				24			11
13	18						17
14			3				
15	4			19			17
16	29		16	4			15
17				16			6
18	32			5			6
19	1		2	13			3
20	6			2			18
21	31		5	15			4
23	6		9	4			10
24	7			9			
25			8				13
26							8
27	19			12			
28				2			15
29	19		14	14			
30							(2)
Nov. 2	2		4	8			
3	23		12	5			
4				14			
5				2			
6	10			7			
7				5			
8				8			
9			1	7			
10				10			
11				8			
13				9			
15				8			
17	11			2			
18			10				
19	9		1	4			
21				3			

[1] Fly escaped.
[2] Died on this date; no eggs in abdomen.
[3] Died on this date.

TABLE II.—*Daily rate of oviposition of the melon flies that emerged on May 25 and were placed separately with fruit on June 25, 1914*—Continued.

Date of observation.	Number of eggs deposited.						
	Fly No. 1.	Fly No. 2.	Fly No. 3.	Fly No. 4.	Fly No. 5.	Fly No. 6.	Fly No. 7.
1914.							
Nov. 22				8			
25	10						
26				3			
27	2						
30				2			
Dec. 1				3			
2	18			4			
6	14						
13			10	1			
14	15			1			
19				1			
20	20						
1915.							
Jan. 3				(1)			
4			1				
8	13						
14	9						
16			3				
27	9						
Feb. 1			(1)				
27	3						
Mar. 26	(1)						
Total	687	94	152	261	134	91	302

[1] Died on this date.

Number of eggs deposited by single females.—It has been difficult to ascertain the maximum egg-laying capacity of individual females owing to the immense amount of time required in keeping the flies supplied with fresh host fruits and in making the daily searches for eggs deposited, and the disadvantages accruing through mortality. It has been shown that the rate of oviposition, as evidenced particularly by the data in Table II among young flies of the same age and kept under identical conditions, varies for no apparent reason. The total numbers of eggs deposited by the 7 females of Table II are 687, 94, 152, 261, 134, 91, and 302, respectively. Fly No. 1 of Table III, which was placed with host fruits for the first time when she was about 13 weeks old, deposited a total of 200 eggs during the remaining 100 days of life. Since Fly No. 1 of Table II deposited 687 eggs during the 10 months of life, and other females kept without access to host fruits deposited eggs during the 398 to 400 days following emergence (Table I), it would appear, as substantiated by the data collected, that under the most favorable climatic conditions in the field a total of 1,000 eggs per female is not too great a number to expect of vigorous and long-lived females.

Oviposition in absence of host plants.—The fact that the flies whose egg-laying capacity is recorded in Tables III and IV were not given an opportunity to oviposit in fruits until 3, 8, and 9 months after emergence does not indicate that sexual development had been completely checked during this interval, or that no eggs were depos-

ited. Females will deposit eggs on the sides of the containing receptacles if they are not given fruit in which to oviposit. They do not seem, however, to deposit as freely as when placed with fruits. A small number of flies, still alive of those emerging from pupæ in February 17, 1914, were observed to lay, as usual, a few eggs on the sides of the containing jars. A record of the eggs deposited was made every few days, beginning with December 17, 1914, and ending April 4, when the last female died. The record of these eggs appears in Table I under the subject of longevity of adults. The dates on which the observations were made were arbitrarily chosen to conform with other laboratory work and are not necessarily those on which the eggs were actually laid. When one considers that these females had no fruit offered them throughout their life, the number of eggs laid is very interesting; thus 11 eggs were deposited between March 22 and 25, or from 398 to 400 days after the flies emerged.

Ability to resume normal oviposition after period of scarcity of host fruits.—The data in Tables III and IV are valuable, inasmuch as they demonstrate that the female melon fly which has been deprived of all opportunity to oviposit in fruit can begin ovipositing at the normal rate when host fruits become available. Thus the three flies whose records are included in Table III had been kept in glass jars from the date of their emergence from pupæ on February 17 until May 22, or about 13 weeks, while the two whose records appear in Table IV were not given an opportunity to oviposit in fruits until October 8 and November 26, respectively, or from about 31 weeks to about 37 weeks after emergence.

TABLE III.—*Daily rate of oviposition of melon flies that emerged on February 17 and were placed separately with fruit on May 22, 1914.*

Date.[1]	Number of eggs deposited.			Date.	Number of eggs deposited.		
	Fly No. 1.	Fly No. 2.	Fly No. 3.		Fly No. 1.	Fly No. 2.	Fly No. 3.
May 22	21			Aug. 3	13		
30	14	2		4			12
31	4		2	8		8	17
June 6		17		9	8		
8		13		10	10		21
15			9	12	10		21
16	1			15			22
17		12		16		12	
21	10			17	12		
23		4		18			14
28			10	19	9		
30	18			22	16		
July 9		7		25	2		
13	3			29		17	
15		16		30	7		
16	3			Sept. 3			[2]
19	16			6	[2]		
21	2			17		12	
24		14		23		29	
26			17	24		[3]	
27	8	28	13				
30			4	Total	200	191	162
31	13						

[1] Dates on which none of the flies oviposited are omitted from the table.
[2] Died on this date; no eggs in abdomen.
[3] Adult lost.

TABLE IV.—*Daily rate of oviposition of two melon flies that emerged on February 17, 1914, and were placed separately with fruit on October 8 and November 26, respectively.*

Fly No. 1, placed with fruit Oct. 8, 1914.				Fly No. 2, placed with fruit Nov. 26, 1914.			
Date of oviposition.[1]	Number of eggs deposited.	Date of oviposition.	Number of eggs deposited.	Date of oviposition.[1]	Number of eggs deposited.	Date of oviposition.	Number of eggs deposited.
Oct. 8	5	Nov. 4	18	Nov. 27	14	Jan. 20	6
10	12	9	13	30	4	26	1
14	12	13	10	Dec. 1	8	Feb. 9	3
17	21	15	2	6	8	16	12
20	7	19	4	13	9	22	3
23	13	27	(2)	17	6	25	3
Nov. 2	3			18	2	Mar. 3	8
				21	7	12	4
				23	6	29	(2)
				27	3		

[1] Dates on which no eggs were laid are omitted from this table.
[2] Died on this date.

Activity in feeding and oviposition.—Like numerous insects in semitropical climates, the adult melon fly rests during the heat of the day in the warmest months. During this part of the day adults may be found resting on the underside of any vegetation offering sufficient protection. During the cooler morning and afternoon hours they may be found flying about their hosts or other vegetation offering food. As cooler weather approaches and during the winter months adults are found feeding and ovipositing at all times of the day, or only during the noon hours if the mornings and evenings are cooler than usual.

MIGRATION OF ADULTS.

Observation indicates that the adult melon fly is a very much stronger flier than the adults of the Mediterranean fruit fly. Its host plants are grown so generally throughout littoral Hawaii that it is difficult to offer conclusive data on distances covered by adults. Examination has shown that adults do not remain upon their host plants exclusively, but that they may congregate in large numbers upon the foliage of any densely growing plant, bush, or tree, either close to or at considerable distance from known host plants. They are able to rove for a number of months where no host plants are available for oviposition, and if, as the longevity of certain individuals in the laboratory would indicate, hardy specimens can subsist for over a year without host plants for oviposition, this radius of migration must be considerable. It is certain that no hosts can be planted in the Hawaiian Islands, no matter how isolated, without very soon being attacked.

Adults do not appear to travel in swarms. It is seldom that one sees more than a single individual at a time feeding upon honeydew

at any distance from the host plants. In the laboratory, however, the adults often gather in small colonies upon the ceiling.

THE EGG.

DESCRIPTION.

The egg (fig. 2) is pure white, about 2 mm. long, elongate elliptical, nearly flat on the ventral surface, more convex on the dorsal. Eggs are often somewhat curved.

DURATION.

The duration of the egg stage of the melon fly is very short. During the warm summer weather of August, 1914, when during the developmental periods the average mean temperature of Honolulu averaged 79.5° F. and the average range in temperature was only 8.3°, 267 eggs hatched in from 26 to 35 hours after deposition. Of these eggs, which were deposited during a period of 1 hour, as shown by the data in Table V, 149, or slightly over 56.6 per cent, hatched within from 26 to 28 hours after deposition. When the average mean temperature for the incubation period averaged 75.6° F. and the daily range in temperature about 10.4°, 84 eggs deposited between 3.15 and 3.30 p. m. on May 19 hatched between 10 p. m., May 20, and 2 a. m., May 21, or within from 31 to 38 hours after deposition. At a mean temperature of about 75° F. 96 eggs hatched within from 33 to 38 hours after deposition. At the still cooler average mean temperature of 73.6° F. 88 eggs hatched between from 40 to 50 hours after deposition.

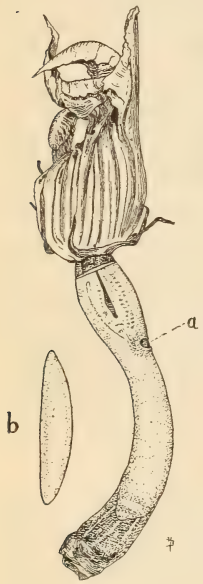


FIG. 2.—The melon fly: *a*, Eggs deposited in cavity in young pumpkin flower; *b*, single egg, enlarged. (Original.)

While the data included in Table V give information regarding the duration of the egg stage in Honolulu or littoral Hawaii in general from April to November, other data show that during January to March embryonic development may require at least 3 to 4 days when the mean temperatures drop to about 69° F. At higher altitudes this period may be appreciably prolonged, due to still lower temperatures, although it is unlikely that at any place where the melon fly is found in Hawaii the duration of the egg stage is more than 6 days. Host fruits containing eggs deposited under normal Honolulu conditions between 10 a. m. and 3 p. m., December 1, were placed, 30 minutes after deposition, in a large refrigerator and held at a temperature varying between 56° F. and 62° F. Examina-

tions made daily by H. F. Willard show that after 4 days 38 out of 174 eggs had hatched at this temperature, while of the 138 still unhatched 103 and 10, respectively, hatched after removal to normal temperature on the fifth and sixth days. After 6 days, 44 out of 64 eggs were found hatched in another lot of fruits examined, and of the 20 eggs removed to normal temperatures but 1 hatched on the seventh day after deposition. Examinations of fruit made after the sixth day prove all eggs either to have hatched or died.

In cold-storage experiments the egg stage was prolonged to at least 12 days. Thirty-four eggs out of 107 in situ in pumpkins gathered in the field May 11, 1914, and held in storage at 49° to 52° F. until May 21, or for 10 days, hatched on May 22, or at least 11 days after deposition. During summer temperatures the duration of the egg stage may be likewise prolonged to as much as 10 days by subjecting the host fruits containing the eggs to temperatures ranging from 35 to 40° F. Table VIII contains data on the effect of cold storage temperatures upon egg mortality.

TABLE V.—*Duration of the egg stage of the melon fly at Honolulu.*

Number of eggs under observation.	Eggs deposited.		Eggs hatched.		Average mean temperature for period.
	Day.	Period.	Day.	Period.	
					°F.
17	Aug. 20	10.30 to 11.30 a. m.	Aug. 21	1 to 2 p. m.	79.5
75	...do.	...do.	...do.	2 to 2.15 p. m.	79.5
45	...do.	...do.	...do.	2.30 to 2.45 p. m.	79.5
12	...do.	...do.	...do.	2.45 to 3 p. m.	79.5
23	...do.	...do.	...do.	3 to 3.15 p. m.	79.5
9	...do.	...do.	...do.	3.15 to 3.30 p. m.	79.5
6	...do.	...do.	...do.	3.30 to 3.45 p. m.	79.5
20	...do.	...do.	...do.	3.45 to 4 p. m.	79.5
9	...do.	...do.	...do.	4 to 4.30 p. m.	79.5
37	...do.	...do.	...do.	4.30 to 6 p. m.	79.5
7	...do.	...do.	...do.	6 to 8 p. m.	79.5
5	...do.	...do.	...do.	8 to 9 p. m.	79.5
2	...do.	...do.	...do.	9 to 10 p. m.	79.5
84	May 19	3.15 to 3.30 p. m.	May 20	10 p. m. to 2 a. m.	75.6
94	May 14	4 to 6 p. m.	May 16	3 to 5.30 a. m.	75.0
13	May 13	10 a. m. to 1 p. m.	May 14	About 9 p. m.	75.5
62	...do.	...do.	...do.	10 p. m. to 3 a. m.	75.5
77	May 11	11.30 a. m. to 2 p. m.	May 13	3 to 6 a. m.	73.6
11	...do.	...do.	...do.	6 to 9.30 a. m.	73.6

HATCHING.

Several hours before hatching the dark-brown head-hooks of the larva can be seen working backward and forward in a probable attempt on the part of the larva to break its way through the egg membranes. The head lies just back of the pointed anterior end of the egg and the larva ultimately breaks through the inner membranes and shell at this end and crawls out through the opening thus made. As the larva pushes its way out, the rupture of the eggshell extends far-

ther and farther back for a distance of from one-half to three-quarters of the length of the egg. The pointed tip of the egg remains uninjured. The eggshell completely collapses as soon as the larva has entirely withdrawn.

FIG. 3.—The melon fly: Newly hatched larva, showing absence of anterior spiracles and main tracheal system. Enlarged. (Original.)

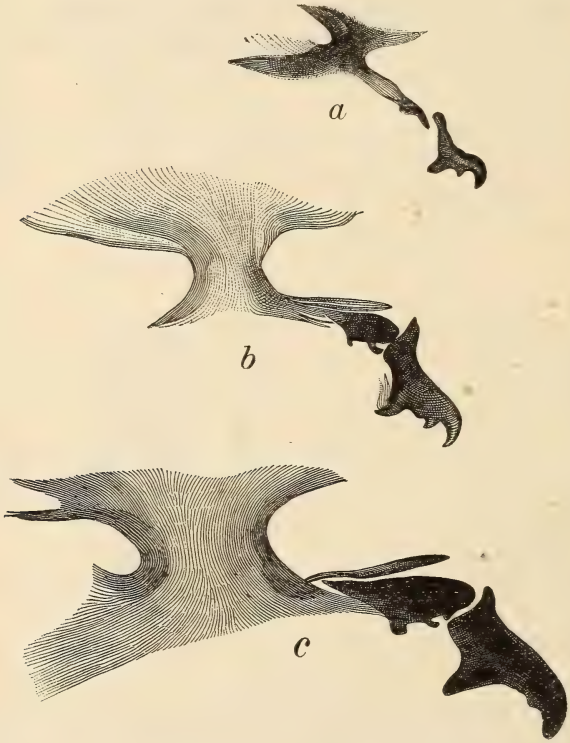


FIG. 4.—The melon fly; Mandibles or mouth hooks of larva. *a*, First instar; *b*, second instar; *c*, third instar. Enlarged. (Original.)

THE LARVA.

DESCRIPTION.

The larva in all instars is pure glistening white, except as appearances are altered by the color of the various host fruits within the alimentary canal. The larva passes through three instars, which

are easily distinguished from each other by differences in structure as well as in size. Unless otherwise noted the Newport or hidden segment is not counted in numbering the segments.

First larval instar (fig. 3).—Length about 2 mm. Mouth hooks small, about 0.45 mm. long and shaped as illustrated in figure 4, *a*. Anterior spiracles found in succeeding instars are lacking. Posterior spiracles minute, being about 0.046 mm. across at the widest point. Stigmal plates approximate, each with two instead of three slits, as shown in figure 5. The fine bristles arranged in three groups about the stigmal plates are somewhat longer than the width of the tracheal trunks at their termination.

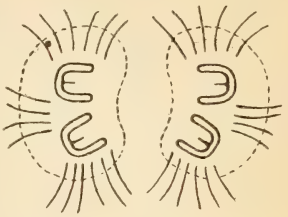


FIG. 5.—The melon fly: Posterior spiracles of first-instar larva. Enlarged. (Original.)

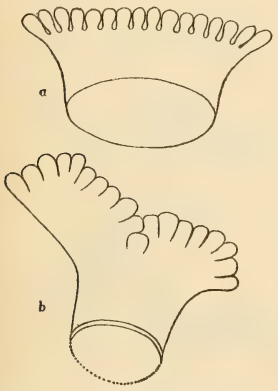


FIG. 6.—The melon fly: *a*, Anterior spiracle of third-instar larva; *b*, anterior spiracle of second-instar larva. Enlarged. (Original.)

Second larval instar.—Length about 5.1 mm. The second-instar larva is sufficiently large to be readily distinguished by its size from the first-instar larva but not from undersized third-instar larvæ. It differs principally from the third-instar larva by the shape of the anterior spiracles (fig. 6, *b*), which are terminated in about 18 to 20 lobes arranged in two groups as the result of a depression in the center of the distal margin of the spiracle. Spiracles about 0.10 mm. wide at the widest point. The posterior spiracles (fig. 7) less heavily chitinized than in the third instar; stigmal plates approximate, each with three slits which are proportionately shorter than those of the third instar. The bristles about the margins of the stigmal plates arranged in four sets instead of three as in the first instar and relatively shorter and finer. Mouth hooks (fig. 4, *b*) about 0.47 mm. long.

Third larval instar (fig. 8).—Length about 10 mm. Head slightly bilobed, at least with two prominent thick fleshy protuberances. Each protuberance bears two pairs of microscopic papillæ, both on the distal portion, but one, the more dorsal, more antennalike in its formation, though without a terminal style or bristle; the more ventral pair but little elevated from the surrounding portions of the body, yet made quite evident by several concentric rings. Mandibles or mouth hooks very distinct, black, about 0.84 mm. long, as illustrated in figure 4, *c*. Mandibles protrude from two openings, one on each side and just anterior to the mouth opening. Between and just anterior to the mandibular openings is a slight protuberance. Labrum distinct, more or less circular, though appearing variously in different alcoholic specimens; lobes about orifice about 20 in number. Anterior spiracles on lateral margins of second segment fan shaped, with distal margin straight or

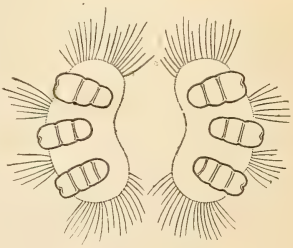


FIG. 7.—The melon fly: Posterior spiracles of second-instar larva. Enlarged. (Original.)

but slightly rounded, bearing 18 or 20 lobes, as illustrated in figure 6, *a*. Posterior stigmal plates very evident, not appreciably elevated or depressed, approximate, each with three well-chitinized slits pointing toward those of the opposite plate as illustrated in figure 9. Slits proportionately longer and narrower than in either of the other instars. The fine bristles about margin of stigmal plate arranged in four sets, relatively finer and shorter than in the second instar. Anal opening on venter of last segment, with a rounded protuberance on either lateral side, the entire area including these protuberances elevated to form a distinct tubercle armed about its base by a concentric area of minute spinules. Body of larva glabrous, except for areas of microscopic spinules arranged as follows: Band on Newport's segment covering the anterior two-thirds of the dorsum but widening ventrally to cover the venter; narrower bands extending about the anterior margin both dorsally and ventrally of the second, third, and fourth segments; fusiform bands composed of broken rows upon the venter only of segments 5 to 12. There are no lateral spinulose areas on segments 5 to 12.

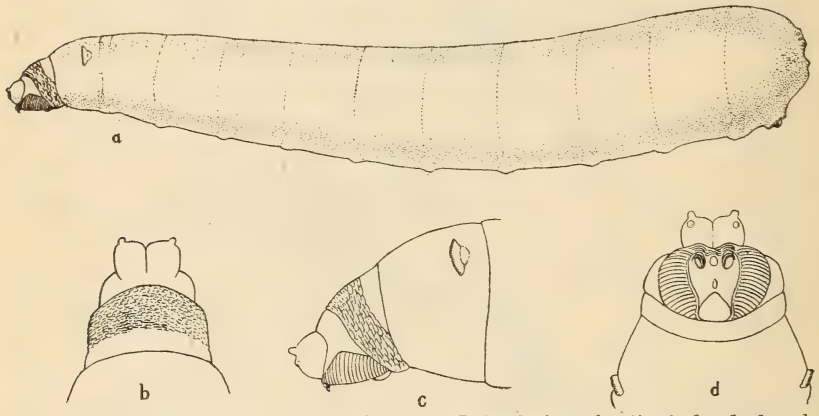


FIG. 8.—The melon fly: Third-instar larva. *a*, Lateral view of entire body; *b*, dorsal view of anterior end; *c*, *d*, lateral and ventral views of same. Enlarged. (Original.)

DURATION OF LARVAL INSTARS.

The larva of the melon fly passes through three instars before becoming full grown. The number of hours passed in each instar has been obtained for the first 12 larvæ recorded in Table VI. These larvæ were transferred daily to fresh pieces of ripe papaya pulp, and were therefore given the best combination of food and temperature for rapid development known to the writers. The majority of these 12 larvæ passed about 1 day in each of the first two instars and about 2½ days in the third instar. An examination of the number of hours for each instar recorded in Table VI shows that variation may occur at times when no apparent cause can be assigned and that a larger number of hours passed in one instar may be followed by fewer hours than usual in the succeeding instar. As shown by the data in Table VI, larval development may be completed in as few

as 4 days, or as many as 17 days, even during the hottest Hawaiian summer weather, when the average daily mean temperatures for the developmental period range between 78.2° and 79.3° F.

Both temperature and the nature of the host fruit affect larval development. Thus while 1 larva reached maturity and pupated in 4 days in fresh ripe papaya at 78.2° F., 2 larvæ required 10 and 13 days, respectively, to reach maturity in a ripe Bartlett pear at about 79° F. The larvæ developing in cantaloupes Nos. 1 and 2, recorded in Table VI, hatched from eggs deposited during a period of 1½ hours while the fruits were confined in a jar with adult melon flies, yet the larval period in one fruit ranged from 7 to 17 days.

Larval life may be extended through the medium of natural barriers to the exit of full-grown larvæ, within favored host fruits, which prevent ready access to the soil, since in small partially dried

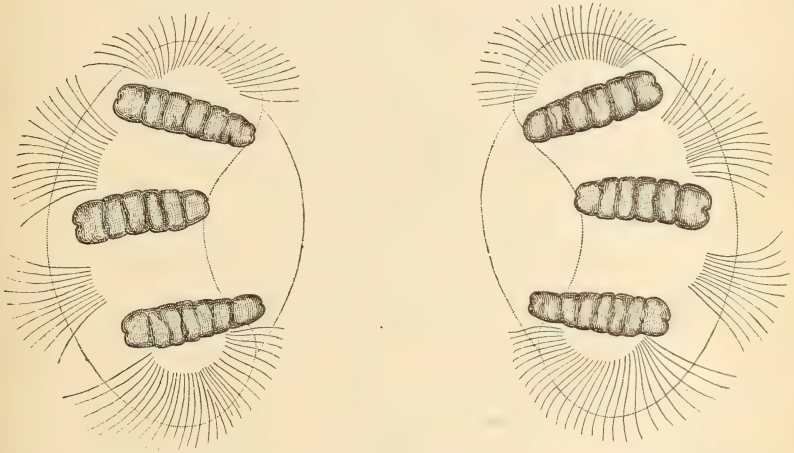


FIG. 9.—The melon fly: Posterior spiracles of third-instar larva. Enlarged. (Original.)

pumpkins, the interior of which is honeycombed by larval channels, the epidermis has become too toughened to permit free larval exit except at one or two places, and larval life thus may be appreciably prolonged. In very moist fruits, such as the ripe tomato, no such barrier to emergence is offered. While larvæ feed best in partial decay resulting from their own feeding, decays due to the work of bacteria or fungi, especially when they become acid, are detrimental to larval growth. These varying factors, which influence either the development of the larva or the time when it succeeds in forming its puparium, make data unaccompanied by notes on temperature and the condition of the host fruit of less value.

Cantaloupes Nos. 1 and 2, the Bartlett pear, and the cucumber, recorded as hosts in Table VI, were sufficiently ripe for table purposes when exposed for oviposition. Larvæ placed in sound green but well-

grown tomatoes matured in from 4 to 7 days; 5, 14, 9, and 2 developing in 4, 5, 6, and 7 days respectively, at an average mean temperature of 78.5° to 79.1° F. Under the same temperature conditions 4 and 5 larvæ required 4 and 5 days, respectively, for development in a ripe tomato.

Lower temperatures than any experienced in Hawaii prolong larval life, although to what extent it has been impossible to determine under out-of-door conditions, because host fruits of this pest decay too rapidly. Eleven out of 23 larvæ that were fully grown when gathered in the field in pumpkins, on May 11, 1913, and placed in a refrigerator kept at 49° to 52° F., were alive when examined on June 3, or 23 days afterward, thus increasing the larval stage to at least 28 to 30 days. At this same temperature, which is sufficiently low to check development, 20 out of 62 first-instar larvæ were alive after 17 days in the refrigerator. These 20 larvæ whose development had been prolonged from about 12 hours to 17 days by the lower temperature to which they had been subjected, after removal to normal temperature of the laboratory continued their development at the same rate and emerged as adults precisely as normal individuals whose development had not been artificially arrested.

TABLE VI.—*Duration of the larval stage of the melon fly at Honolulu.*

Number of specimens under observation.	Approximate period of development.	Host fruit.	Number of hours in—			Period in larval stage.		Average mean temperature for period of development.
			Instar 1.	Instar 2.	Instar 3.			
						Days.	*Hrs.*	°*F.*
1	Sept. 18 to 22	Ripe papaya	24	36	36	4	..	78.2
1	Sept. 25 to 29	do	24	24	50	4	2	79
1	do	do	24	25	54	4	7	79
1	do	do	25	25	51	4	5	79
1	Sept. 25 to 30	do	27	25	60	4	16	79
1	do	do	26	40	52	4	22	79
1	Sept. 27 to Oct. 4	do	24	24	60	4	12	78.2
1	do	do	23	23.5	60	4	10	78.2
1	do	do	23.5	22	60	4	10	78.2
1	do	do	23.5	23.5	60	4	11	78.2
1	do	do	22.5	23	60	4	11	78.2
1	do	do	25.1	36	60	5	1	78.2
1	Aug. 21 to 31	Bartlett pear	.....	.....	.....	10	..	79
1	Aug. 21 to Sept. 2	do	.....	.....	.....	13	..	79.2
28	Aug. 21 to 27	Cucumber	.....	.....	.....	6	..	79
38	Aug. 21 to 28	do	.....	.....	.....	7	..	78.8
4	Aug. 21 to 29	do	.....	.....	.....	8	..	78.8
61	Aug. 21 to 28	Ripe cantaloupe No. 1.	.....	.....	.....	7	..	78.8
98	Aug. 21 to 29	do	.....	.....	.....	8	..	78.8
70	Aug. 21 to 30	do	.....	.....	.....	9	..	78.9
18	Aug. 21 to 31	do	.....	.....	.....	10	..	79
8	Aug. 21 to Sept. 1	do	.....	.....	.....	11	..	79
2	Aug. 31 to Sept. 2	do	.....	.....	.....	12	..	79
3	Aug. 21 to Sept. 3	do	.....	.....	.....	13	..	79.2
1	Aug. 21 to Sept. 7	do	.....	.....	.....	17	..	79.3
12	Aug. 21 to 26	Ripe cantaloupe No. 2.	.....	.....	.....	5	..	79.1
55	Aug. 21 to 27	do	.....	.....	.....	6	..	79
42	Aug. 21 to 28	do	.....	.....	.....	7	..	78.8
5	Aug. 21 to 29	do	.....	.....	.....	8	..	78.8
1	Aug. 21 to 30	do	.....	.....	.....	9	..	78.9

HABITS.

The larvæ immediately upon hatching within the egg cavity or puncture begin to feed upon the surrounding tissues of the host. In one instance only were they observed to desert the host through the punctured epidermis. In this instance the eggs from which they hatched had been deposited under forced laboratory conditions in a firm-textured apple, which is not ordinarily a host fruit. The larvæ on hatching deserted this fruit only to die on the exterior a short distance from the point of emergence.

Ordinarily the young larvæ begin immediately to burrow into the pulp of the host, and in the case of many fruits they burrow at once to the center, where they feed until well grown. When the fruits are of a watery texture, or of a very firm texture, the larvæ prefer or are forced to feed near the epidermis. In decayed spots in tomatoes or cucumbers and like fruits, which have become filled with rain water, the larvæ come to the surface for varying intervals and remain in rather dense formation, each larva perpendicular to the moisture level, with its posterior spiracles protruding. In this position the mass of larvæ remains very quiet unless disturbed. All larvæ are forced to come to the surface for air unless their tunnels are formed within a host sufficiently free from excess moisture to permit air to penetrate freely the larval channels. When hatching from eggs deposited in open wounds in well-developed pumpkins or squashes, the larvæ find it impossible to penetrate to the interior, but are able to make full development in the outer portion. (Pl. XX.)

When the larvæ have emerged from one host fruit they do not enter another except when numerous infested fruits are present in a single container, and when all are more or less decayed. The writers have not observed larvæ, having emerged from their host, burrow into sound fruits close by. Larvæ, however, have been observed to burrow into the decayed areas in other fruit touching the original host fruit, and, being found there, have been recorded as attacking that fruit, whereas their presence is accidental.

The larva of the melon fly, in common with that of the Mediterranean fruit fly, has a peculiar habit of jumping after it has left the host. Larvæ in the first two instars are unable to spring if taken from the host. The mature larva arches its body so that it is able with its mouth hooks to obtain a leverage on the posterior end of the body. This done, with a sudden muscular relaxation it is able to spring from a few to as many as 8 or 9 inches into the air or sideways. The larvæ continue to jump after leaving the host until they find a suitable place for pupation. They are not able to jump con-

stantly in any given direction, hence they seldom get far from the point of emergence. Larvæ have been observed to travel 15 feet on concrete floors, but in the field, under usual conditions, they enter the soil to pupate directly beneath the host fruit and do not exercise to any extent this power of locomotion. When the soil is very hard the larvæ pupate beneath any object, or even upon a bare surface, as the floor of a room. On hard moist soils larvæ usually pupate upon or just beneath the surface. In the more porous soils pupation occurs at various depths, but rarely deeper than from 1 to 1½ inches. It is seldom that larvæ are unable to find their way out of their host, but when they can not they sometimes pupate within the host. Larvæ have been known to pupate in bean pods where they are imprisoned by the drying out of the pod. Pupation is apt to occur in any of the more firmly textured host fruits.

PREPUPAL PERIOD.

The writers have chosen to look upon the pupal stage as beginning with the formation of the puparium and to refer to the duration of the pupal stage as that period between the formation of the puparium and the emergence of the adult. During the warmer seasons the contraction of the larvæ to form the puparium begins very soon after the larva emerges from the host fruit, and is completed within an hour. Larvæ forced to leave fruit prematurely may remain active for as long as two days under certain conditions, but invariably die without forming a puparium if the puparium is not formed for so long a time after emergence. Fifteen puparia formed between 11 a. m. and 1 p. m., February 3, were dissected one day later, but there was no indication of a true pupa within; no organization of internal structures could be seen except a pulsating heart. On February 5, however, or two days after the formation of the puparium, the examination of 15 puparia showed the true pupa, which was well formed and free within the puparium case. The average mean temperature during this 2-day period was 72° F., with a daily average of from 66° to 78° F. The relative mean humidity ranged between 75 and 78 per cent.

THE PUPA.

DESCRIPTION.

Puparium (fig. 10).—Length about 5 to 6 mm. Elliptical, varying in color from dark testaceous to dull white, according to host. Being composed of the larval skin, it is natural that the markings of the larva should be found on the puparium. The puparium appears to consist of 12 segments, although when treated with potash the first is found to be composed of the first and

second larval segments. When viewed from above the anterior spiracles are situated upon the outer anterior angles, and the posterior spiracles upon the central region of the posterior margin (fig. 10, *a*). When viewed from below (fig. 10, *b*) the anal opening of the larva appears as a rounded black spot on the twelfth segment, and the mouth opening as a depression in the central portion of the first segment. The broken spinulose bands upon the ventral surface of the larva appear upon segments 6 to 11 of the venter of the puparium as two narrow bands not encroaching upon the lateral sides. Between the posterior spiracles and the anal opening is a distinct transverse blackish line (fig. 10, *c*).

DURATION OF PUPAL STAGE.

During the warmest summer weather at Honolulu, when the daily mean temperatures average between 78.7° and 79.4° F. and

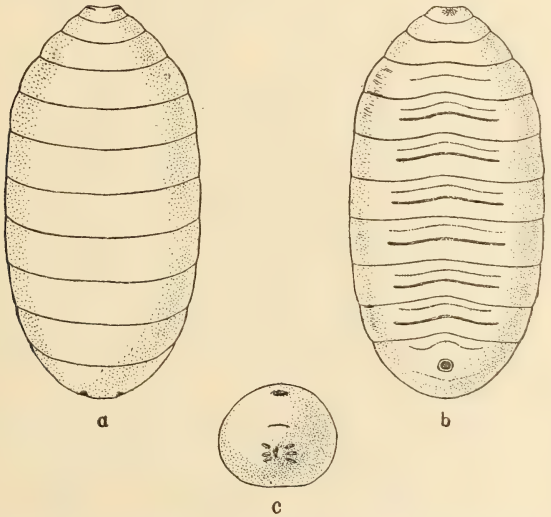


FIG. 10.—The melon fly: Puparium. *a*, Dorsal view; *b*, ventral view; *c*, view showing the posterior spiracles, oval depression, and dark line marking on posterior portion. Enlarged. (Original.)

the relative mean humidity between 64 and 70.2 per cent, by far the largest number of pupæ require 9 days for development. Of 896 pupæ, as shown by the data in Table VII, 67, 743, 85, and 1 yielded adults 8, 9, 10, and 11 days, respectively, after the formation of the puparium. During the cooler months of February, when the average mean temperature was 71.6° F. and the average mean relative humidity was 74.3 per cent, 83 and 420 pupæ required 12 and 13 days, respectively, to produce adults. From 1,037 pupæ not recorded in Table VII, 6, 125, 881, and 25 adults emerged within 7, 8, 9, and 10 days, respectively, after the formation of

the puparia, when the average mean temperature ranged from 78.7° to 79.4° F.

During the winter months in the Kona district of Hawaii, where the lowest mean temperatures at Kealakekua were about 68° F., with a daily temperature ranging between 58° and 78° F., the duration of the pupal stage is considerably lengthened. Thus 7, 6, and 1 pupæ yielded adults 20, 21, and 22 days, respectively, after the formation of the puparium. From 175 puparia formed between the 1st and 3d of February, 2, 7, 151, 12, and 3 adults emerged on February 20, 21, 22, 23, and 24, respectively. At Kaawaloa, a hot sheltered spot at sea level, but within 2 miles of the station at Kealakekua, where the temperature ranged from 63° to 89° F., 126 pupæ formed on February 23 produced 5, 107, and 2 adults on March 5, 6, and 7, respectively, or in from 10 to 12 days after the formation of the puparium.

It was found by carrying pupæ to higher altitudes than those at which the host fruits of the melon fly occur in Hawaii that the duration of the pupal stage might be considerably lengthened. Thus 143 puparia just formed at Kealakekua on January 26, 1915, were taken the same day to Puulehua at about 5,000 feet elevation, where the average mean temperature from January 14 to March 19 was about 51.6° F. and where the daily range in temperature showed a variation from a minimum of 31° F. to a maximum of 72° F. From these pupæ, removed to Kealakekua on March 25, 3 adults emerged on March 26. Therefore at this temperature the duration of the pupal stage may be at least 59 days.

One hundred and twenty-four pupæ formed between February 19 and 21, 1915, and 76 pupæ formed on February 22 and 23 at Kealakekua were taken on February 24 to the summit of Hualalai, 8,275 feet elevation, where the average mean temperature during February and March was about 46.3° F. and the daily range from a minimum of 27° F. to a maximum of 73° F. These pupæ were removed to Kealakekua on March 26 and on March 31, 6 and 1 adult flies, respectively, emerged. For these 7 pupæ the duration of the pupal stage extended from 36 to 40 days.

It is the opinion of the writers that had it been possible to continue experimental work at Puulehua and on Hualalai, the duration of the pupal stage might have been still further extended, but not by very many days.

TABLE VII.—*Duration of the pupal stage of the melon fly at Honolulu.*

Date of pupation.	Date of emergence.	Number of adults emerging.	Number of days in pupal stage.	Average mean temperature.	Average mean relative humidity
				°F.	*Per cent.*
Aug. 14, a. m.	Aug. 22, a. m.	5	8	78.7	72.5
Do.	Aug. 23, a. m.	25	9	78.9	71.6
Do.	Aug. 25, a. m.	1	11	78.9	70.8
Aug. 17, a. m.	do.	60	8	79.3	69.4
Do.	Aug. 25, p. m.	1	8.5	79.3	68.7
Do.	Aug. 26, a. m.	27	9	79.2	68.7
Aug. 18, a. m.	Aug. 25, a. m.	1	7	79.3	67.8
Do.	Aug. 26, a. m.	17	8	79.4	67.2
Do.	Aug. 27, a. m.	25	9	79.4	66.6
Sept. 17, a. m.	Sept. 26, a. m.	26	9	79.2	72.1
Do.	Sept. 27, a. m.	37	10	79.2	70.8
Sept. 20, a. m.	Sept. 29, a. m.	355	9	79.4	69.4
Do.	Sept. 30, a. m.	33	10	79.3	69
Sept. 19, a. m.	Sept. 28, a. m.	300	9	79.4	70.1
Do.	Sept. 29, a. m.	15	10	79.3	69.5
Feb. 3, a. m.	Feb. 15, a. m.	45	12	71.6	74
Do.	Feb. 16, a. m.	192	13	71.6	74.2
Feb. 4, a. m.	do.	38	12	71.6	74
Do.	Feb. 17, a. m.	228	13	71.6	74.2

LENGTH OF LIFE CYCLE.

During the warmest Hawaiian weather, when the mean temperature averages about 79.5° F., the egg, larval, and pupal stages may be passed in as few as 12 or as many as 28½ days, according to the individual and its host. The complete life cycle is subject to great variation, according to the longevity of the adult. As one adult has been kept alive for 431 days it is evident that the complete life cycle from the deposition of egg to the death of the adult may be 443 to 459 days when the immature stages are passed during the warmer portion of the year. At an average mean temperature of about 68° F., which is the coolest mean temperature found by the writers in Hawaii, where host fruits are available for the fly and for observation, the egg, larval, and pupal stages are passed in from 40 to 45 days. It is difficult to state just what variation there may be in the length of the life cycle in still cooler climates, but it is capable of being rather great in the opinion of the writers. The pupal stage in Hawaii has been lengthened from 6 days at a mean of 79° F. to 59 days at a mean out-of-door temperature of about 5.6° F. In like manner the egg stage has been lengthened from 26 hours at 79° F. to 11 days at 49° to 52° F. in storage, the third larval stage from two days at 79° F. to at least 23 days at 56° to 62° F., and the first larval stage from 20 hours at 79° F. to 27 days at 56° to 62° F. The writers believe that with certain combinations of host fruits and temperatures the immature stage may require 3½ to 4 months, or a sufficiently long time to carry the pest over any cool period likely to be experienced by the melon fly in any habitat where it can establish itself.

SEASONAL HISTORY.

In littoral Hawaii there may be from 8 to 10 generations of the melon fly a year when one considers the length of a generation as extending from the time the eggs are laid until the female of the next generation begins to deposit eggs. As the females are capable of living many months and of depositing eggs at frequent intervals throughout life, the generations so overlap each other that adults present in the field at any one time may belong to generations started in any month of the year. It is possible for females ovipositing on January 1 to be still alive and ovipositing the following January along with the progeny of the tenth generation of her descendents.

In the Hawaiian Islands, where the climatic conditions permit breeding throughout the year, adults of the melon fly are abundant at all seasons in the littoral regions, where, for the most part, host plants are grown. There is no evidence of seasonal broods or generations of adults. That the cooler weather of the winter months does lengthen the duration of the immature stages has already been proved by data. This slowing down of development naturally results in the emergence of fewer adults, and in forcing these to feed for a greater period of time before becoming sufficiently developed to oviposit. Unfortunately the length of adult life and the capacity of the females for continued egg laying makes it difficult for market gardeners to benefit to any marked extent from the effects of cool weather upon development if they allow their fruits to remain unprotected. The fewer adults, coupled with the shorter hours during the day when they are sufficiently active to oviposit, does result in greater success in saving fruits by the use of various protective coverings than would follow the use of the same measures in the summer. At an elevation of 1,500 to 2,000 feet in the Kona district of Hawaii, where the winter mean averages about 68° F., and where the melon fly can breed in large numbers in wild hosts, fully 50 per cent of the pumpkins and squashes are able to mature even if left uncovered. Adults were present at an elevation of 4,000 to 4,500 feet in the island of Hawaii and ovipositing in young squashes. These squashes were examined and found to contain eggs and larvæ. As the vines bearing these fruits were later killed by frosts, it seems possible to conclude, at least for this locality, that the melon fly is able to survive in climates too cold to permit its host plants to grow continuously throughout the year.

METHOD OF SPREAD.

The melon fly is probably more often carried from one locality or country to another in the larval stage than in any other form. Maskew (42) has recorded finding living larvæ in host fruits arriving at San Francisco on ships from Honolulu, and his records prove that the melon fly in the larval stage is able to bridge the 6 or 7 days

required by the slower vessels to cover the 2,000 miles between the Hawaiian Islands and California, since he intercepted it at least once a year during 1912, 1913, 1914, and 1915. Data regarding the duration of the immature stages show that host fruits taken on board ships as ship's stores are capable of carrying the melon fly, either as larvæ or later as pupæ in the fruit containers, for voyages much longer than that required to cross the Pacific Ocean; or, in other words, are capable of being the means of spreading the pest in vessels plying between almost all countries where climatic conditions are favorable for the establishment of the fly. There is no doubt that the melon fly was carried to the Hawaiian Islands in host fruits taken on ships at Japan or China, and later spread from Honolulu to all the islands of the Hawaiian group in a like manner through the medium of inter-island boats.

While the spread, from one country to another at a considerable distance, probably starts with the fly in the larval stage, the spread from town to town, or over short distances, as between islands of an archipelago, may occur in the adult or pupal stage. The writers have seen female flies alight on an automobile top and be carried 16 miles, from the country into the city of Honolulu. On another occasion an adult was seen flying about an inter-island boat en route from Honolulu to Hilo, on the island of Hawaii. This fly was not observed after the boat weighed anchor at the port of Lahaina on the island of Maui, or 72 miles from Honolulu. These two instances will explain the spread of the pest, in the adult stage, about the islands of Hawaii, even if it could not be transported in the larval stage.

When larvæ form their puparia on bare surfaces, and particularly on a cloth surface, the puparia adhere sufficiently well to make it possible for them to be transported considerable distances under favorable circumstances. While the writers know of no instance where the melon fly has been thus spread, distribution in this fashion is quite feasible and to be expected.

CONTROL MEASURES.

NATURAL CONTROL.

There are no agencies at present working in the Hawaiian Islands that bring about, even periodically, a very large natural reduction in the abundance of melon flies. The mortality among eggs and larvæ is not sufficient to attract attention, except under conditions considered below, and then is not effective enough to be of practical value as a control measure. Were bacteria and fungous diseases at work, the results of such activities would have been evident to the writers during the past several years. The death rate among adult melon flies must be high, or the natural increase of the pest would produce far greater swarms of them than are now present in fields. While Severin (45) has recorded rearing 3 specimens of the hornfly

parasite (*Spalangia hirta* Haliday) from 500 puparia of the melon fly, both he and the writers appreciate that this parasite is of no value at present as a control agent, and, for all practical purposes, can not be considered a factor in repression. Although the writers have reared adult flies from many thousands of larvæ, they have never reared a parasite during a period of 3 years. This is true, notwithstanding the fact that melon-fly pupæ have been used experimentally (39) in the laboratory for rearing the Mediterranean fruit-fly parasites, *Opius humilis* Silv. and *Diachasma tryoni* Cam. Five thousand pupæ of the melon fly, secured from Chinese cucumbers (*Momordica* sp.) growing wild near coffee fields in the Kona district, Hawaii, during 1914 and 1915, produced no parasites, although the pupæ of the Mediterranean fruit fly secured from the coffee cherries showed a parasitism ranging from 85 to 98 per cent.

The great need for methods of natural control has been appreciated, and the Hawaiian Board of Agriculture and Forestry employed Mr. D. T. Fullaway to search for and introduce parasites of the melon fly to Hawaii from the Indo-Malayan region. Mr. Fullaway has returned to Honolulu after travel in India and the Philippines, but the results of his investigation have not yet been made ready for publication. It may be stated, however, that he has introduced an opiine parasite, which gives promise at the present time (June, 1916) of becoming successfully established in the Hawaiian Islands.

The mortality among the eggs and larvæ noted occurs chiefly in rapidly-growing cucurbits, particularly during the cooler seasons, when climatic conditions arrest fly development, but not to the same degree as that of the host, and to a less degree in much older fruits during the warmer seasons. Death among eggs and the young larvæ follows the development of a gall-like hardening about the egg cavity, and on occasion about the newly made burrow of the first-stage larva. This gall-like formation develops rapidly, particularly in such hosts as the gourd and watermelon. While both of these hosts are very susceptible to repeated attacks, individual fruits often succeed astonishingly well in throwing off fatal attack by such formations as that illustrated in Plate XXI, figure 1. The writers have seen large gourds used for household purposes by the poorer population which on the outer side of the rind showed the open breaks made by many colonies of eggs and young larvæ, while the inside showed all ruptures of the epidermis to be sealed by a hard gall, variously formed by the proliferation of plant tissue. The following data resulting from the examination of a young watermelon 3 inches in diameter on April 19, 2 days after it was gathered from the field, will serve as a fair example to illustrate this mortality and are representative of other data on file.

Puncture 1: Twelve unhatched and fresh-looking eggs in a newly made cavity. No gall-like formation evident.

Puncture 2: Nine dead first-stage larvæ and 7 dead third-stage larvæ; all in tough hard gall about one-half inch in diameter.

Punctures 3 and 4 (merged): Eighteen living and one dead first-stage larvæ in a callous dark-brown spot beneath the puncture. Living larvæ moderately active but apparently dying and unable to get out of gall-like formation surrounding them.

Punctures 5 and 6 (merged): Eight living and 6 dead first-stage larvæ in conditions similar to those in punctures 3 and 4.

Puncture 7: Four dead first-stage larvæ dark brown in color.

Puncture 8: Sixteen dead first-stage larvæ dark brown in color.

Puncture 9: Seventeen dead first-stage larvæ dark brown in color.

The data just given would indicate, if considered alone, that the mortality resulting from the gall-like formations might be of practical value; however, under Hawaiian conditions they are of negligible value. In the field from which the watermelon examined was taken, all the very young fruits were badly stung. The 3-inch specimen examined was one of the comparatively few which had resisted attack, and it would have been rendered worthless by the deformities developing about the punctures, even if it did not break down under continued attack by the fly or through decay.

Larvæ die if forced to feed on the decay resulting from bacterial or fungous diseases of the host. While on occasion 90 per cent of all larvæ within a decaying fruit may be found dead, the duration of egg and larval life is so short that mortality resulting from decay is relatively small and unimportant. Mortality among larvæ within bean pods is occasionally due, apparently, to excessive dryness developing with the maturing of the pod. Excessive sun heat kills a few larvæ in fruits well exposed, and the common and abundant introduced harvester ant *Pheidole megacephala* Fab. is responsible for the destruction of some larvæ and adults. In climates colder than the Hawaiian littoral climate mortality due to coldness will be found to play a particularly active part in reducing the abundance of the melon fly. This, however, is not a factor in Hawaii.

ARTIFICIAL CONTROL.

No satisfactory artificial control measures have been successfully applied in controlling the melon fly under Hawaiian conditions. The only means now employed in Hawaii to safeguard fruits is that of protecting the young fruits with some type of covering until they are large enough to withstand attack. Trapping the adults and killing them by spraying have thus far given poor results, while killing the immature stages by submergence in water, burial in soil, or by cold-storage temperatures are methods to be applied in lessening the abundance of the pest only after infestation has taken place within the host fruit. If all growers of host plants would systematically

cooperate (1) in the destruction of the eggs and larvæ by submergence in water and (2) in the destruction of the adults by spraying, the value of spraying with a poisoned bait, and of covering the young fruits, would be enhanced to a point where either might be sufficiently effective to be recommended as satisfactory; but so long as the cultivation of host plants is largely in the hands of uneducated orientals who are not amenable to instruction, no relief can be expected.

Spraying.—Since adult melon flies do not begin ovipositing until from 10 to 14 days after emergence, depending upon the temperature, but feed continuously throughout this period, it is evident that any spray that will kill them before they begin ovipositing is valuable. Severin (45) and Marsh (27) have shown that poisoned-bait sprays are capable of killing adult flies in large numbers, as has already been demonstrated by Mally and Bezzi in the case of the Mediterranean fruit fly. But good results promised by the work of Mally and Bezzi were found by Severin, Marsh, and the writers in Hawaii to be offset by adverse conditions, such as frequent showers and lack of concerted action by those growing host fruits. Marsh, who sprayed beds of cucumbers with a solution made of 1 quart of molasses, one-fourth ounce of Paris green, and 1½ gallons of water, daily from September 9 to October 14, obtained negative results. This was true also when arsenate of lead was used instead of Paris green. Severin found that sprays containing a soluble poison, such as potassium arsenate or sodium arsenite, killed off enormous numbers of adults quickly but "burned the foliage, and can not be advocated." He was unable by spraying to protect young watermelon plants, because he could not control the outside sources for adults and because of the frequent showers.

The writers have obtained negative results in their work with the poisoned spray:

Lead arsenate (paste)	5 ounces.
Brown sugar	2½ pounds.
Water	5 gallons.

About 2 acres of Chinese melons and cucumbers in a field fairly well isolated, which from the Hawaiian standpoint means that no host fruits were growing within 500 yards, were sprayed on May 21, 26, and 28, June 1, 4, 8, 14, and 23, 1915, during typical summer weather. At the beginning of the experiments the young fruits were badly stung. Every fruit under 2 inches long was infested unless it had been properly covered, and adult flies were very numerous. The spray was applied at the rate of about 30 gallons to the acre by means of a knapsack sprayer. The abundance of living adults was so noticeably lessened after the third application that even the Chinese gardeners noted the fact, and for the first time during the experiment showed a willingness to cooperate. The interval be-

tween June 14 and 23 was sufficient to permit an accumulation of adults equal to that at the beginning of the experiment. Six hours after an application no dead flies could be found, though many were sluggish and flew with difficulty. Twenty-four hours after an application many flies could be found dead among the vines. While the adults were lessened numerically, the young fruits were as badly punctured at the end of the experiment as at the beginning. Dr. Illingsworth, of the College of Hawaii, has had only negative results in his experiments to save cucurbit crops by spraying, although he has been able to kill large numbers of adults.

While the writers have had negative results with poisoned-bait sprays, they feel that their failure has been due to peculiar conditions surrounding the fields sprayed. Under commercial conditions, where cantaloupes, pumpkins, and watermelons are grown in large quantities in fairly dry climates, it is reasonable to believe that sufficiently good results will follow the use of poisoned sprays to make their application practicable as a method of control. In Hawaii the growing of these crops is in the hands of Orientals, who do not appreciate the necessity for clean cultural methods as an adjunct to spraying. Their gardens, scattered here and there, form excellent breeding places and centers of distribution. These conditions, coupled with the very long life of the adult and its roving disposition, make it impossible to protect small fields of host plants in Hawaii at the present time by spraying, particularly during the warm season of the year.

Cold storage.—The only data on the effect of cold-storage temperatures upon the immature stages of the melon fly are those included in Tables VIII and IX. Fewer experiments have been carried on by the writers to determine the effect of cold-storage temperatures upon the melon fly than upon the Mediterranean fruit fly, since it has been found that the stages of the former are not more resistant. Consequently host fruits refrigerated for periods sufficiently long to kill the Mediterranean fruit-fly eggs, larvæ, and pupæ are free from danger as carriers of the melon fly; i. e., if refrigerated at from 40° to 45° F. for 7 weeks; from 33° to 40° F. for 3 weeks; or from 32° to 33° F. for 2 weeks when the humidity ranges between 80 and 91. A comparison of the data in Tables VIII and IX with those already published on cold-storage effects upon the immature stages of the Mediterranean fruit fly indicates that the eggs and larvæ of the melon fly and Mediterranean fruit fly are about equally resistant to cold-storage temperature, but that the pupæ of the melon fly are much more susceptible. While no pupæ of the melon fly survived refrigeration at from 32° to 33° F. or from 34° to 36° F. for 5 days, or from 36° to 45° F. (averaging 38° F.) for 9 days, pupæ of the Mediterranean fruit fly were not found to be

entirely killed until refrigerated for 10 days at 32° F., 18 days at 33° to 36° F., or 21 days at 38° to 40° F. No larvæ of the melon fly survived more than 14 days of refrigeration at 35° to 36° F., or 36° to 40° F.; no larvæ of the Mediterranean fruit fly survived more than 12 days at 34° to 36° F., 11 days at 36° to 40° F., or 20 days at 38° to 40° F. No eggs of the melon fly survived cold storage at 35° to 36° F. and 36° to 40° F. for more than 10 days, while no eggs of the Mediterranean fruit fly were found alive after refrigeration at 36° F. and 36° to 40° F. for 12 days.

It is anticipated that these data will be of special value from a quarantine standpoint. The favorable host fruits of the melon fly are fruits which do not adapt themselves to long periods of refrigeration and are subject to serious attack only when they are very young and succulent, except such fruits as the cantaloupe, cucumber, and tomato. The melon-fly host fruits are classed among the quickly perishable fruits, unless exception be made of certain varieties of well-matured squashes and pumpkins. In experimental work the writers have had difficulty in keeping host fruits in fit condition until the larvæ infesting them had been killed by refrigeration. This was particularly true at the temperature of 49° F.

TABLE VIII.—*Effect of cold-storage temperatures upon eggs and larvæ of the melon fly.*

Number of days in cold storage.	Temperature of storage room.	Eggs.		Larvæ.					
		Number under observation.	Number hatching after removal from store.	First instar.		Second instar.		Third instar.	
				Number alive.	Number dead.	Number alive.	Number dead.	Number alive.	Number dead.
	°F.								
7	35 to 36	3	1	8	64	48	77	89	145
10	.....	67	0	1	595	2	364	14	440
12	.....	172	0	0	260	0	215	4	218
14	.....	47	0	0	172	0	299	0	336
16	.....	52	0	0	85	0	288	0	301
18	.....	32	0	0	263	0	363	0	815
20	.....	0	0	0	243	0	379	0	676
22	.....	31	0	0	134	0	265	0	318
6	36 to 40	75	15	85	124	12	49	12	13
7	.....	14	0	19	10	43	34	25	63
9	.....	78	1	0	65	0	114	2	18
10	.....	0	0	0	49	5	78	51	223
11	.....	147	0	0	124	0	105	0	140
12	.....	0	0	0	60	0	45	5	186
13	.....	78	0	0	107	0	104	0	26
14	.....	0	0	0	78	0	155	1	320
15	.....	72	0	0	96	0	82	0	84
17	.....	135	0	0	35	0	126	0	61
18	.....	0	0	0	48	0	130	0	291
20	.....	0	0	0	64	0	122	0	258
22	.....	0	0	0	21	0	126	0	108
7	49 to 52	87	1	0	0	0	0	0	0
8	.....	83	0	0	0	0	0	0	0
9	49 to 52	282	0	51	13	1	30	17	11
10	.....	107	34	16	63	66	16	74	12
12	.....	31	0	0	6	2	9	32	49
17	.....	72	0	20	44	0	4	19	10
21	.....	0	0	0	0	0	0	80	76
23	.....	250	0	0	8	0	0	11	12

TABLE IX.—*Effect of cold-storage temperatures upon the pupæ of the melon fly.*[1]

Temperature of storage room.[2]	Number pupæ under observation.	Age on entering storage.	Number of pupæ yielding adults after removal to normal temperature after refrigeration for—										
			3 days.	4 days.	5 days.	7 days.	9 days.	11 days.	13 days.	15 days.	17 days.	19 days.	24 days.
°F.		Days.											
32° to 33°..	425	2	7 (100)	0	0	0	0	0	0	0	0	0	0
	785	3	5 (125)	0	0	0	0	0	0	0	0	0	0
	1,020	4	0	0	0	0	0	0	0	0	0	0	0
	1,945	5	0	1 (245)	0	0	0	0	0	0	0	0	0
	3,175	6	0	0	0	0	0	0	0	0	0	0	0
	2,165	7	4 (200)	0	0	0	0	0	0	0	0	0	0
34° to 36°..	505	2	7 (90)	.....	0	0	0	0	0	0	0	0	0
	640	3	5 (45)	.....	0	0	0	0	0	0	0	0	0
	985	4	6 (175)	.....	0	0	0	0	0	0	0	0	0
	2,390	5	2 (145)	.....	0	0	0	0	0	0	0	0	0
	2,104	6	3 (195)	.....	0	0	0	0	0	0	0	0	0
	1,813	7	9 (195)	2	0	0	0	0	0	0	0	0	0
36° to 45°..	1,975	6	21(170)	.....	12	3	0	0	0	0	0	0	0

[1] Numbers in parentheses refer to total numbers of pupæ removed after refrigeration for the length of days indicated.
[2] Average, 38° F.

Submergence in water.—Submergence of host fruits containing the immature stages of fruit flies has been recommended by many writers as an easily available method of controlling these pests. Severin (45) has published the first data on the effects of submergence upon the melon fly. In his work he submerged beneath 7 inches of distilled water three lots of 100 full-grown larvæ which had emerged from their hosts to pupate. One lot was removed after having been submerged 2, 3, and 4 days. After being allowed to dry upon filter paper, 75, 16, and 0 larvæ pupated and later yielded 47, 5, and 0 adults, respectively. From these data Severin concluded that submergence of infested vegetables in a barrel or tank of water for a period of 4 days would be sufficient to insure the death of larvæ within them.

Instead of submerging isolated larvæ, the writers have submerged infested cucumbers in ordinary tap water at a mean temperature of 78° F. The results of daily examination of the larvæ within these fruits on submergence from 1 to 6 days are given in Table X. It will be noted that many larvæ survive a submergence of 1 and 2 days successfully. On the third day but 6 out of 207 larvæ in the second and third instars were found living. But 1 out of 374 larvæ withstood submergence 4 days. All of 514 and 773 larvæ found in fruits submerged 5 and 6 days were dead.

Pupæ submerged in tap water survived slightly longer than larvæ, as indicated by the data in Table XI. Fourteen out of 52 pupæ that were from 2 to 4 days old when immersed yielded adults after removal from the water. Only 1 out of 77 pupæ of like age submerged 5 days survived and yielded an adult, while all of 91 submerged 6 days died. The young pupæ apparently die more

quickly than the older pupæ when submerged. Only 2 of 79 pupæ 1 and 2 days old, respectively, survived submergence for 2 days. Two out of 156 and 1 out of 163 pupæ submerged 3 and 4 days, respectively, survived. Other pupæ 1 and 2 days old submerged 5, 6, and 7 days died.

It is safe to conclude that the larvæ of the melon fly will be killed when the host containing them is submerged in water for 5 days and the pupæ after submergence for 6 days.

TABLE X.—*Effect of submergence in ordinary soft water upon larvæ of the melon fly within cucumbers.*

[Daily mean temperatures for period 69.5° to 71° F., averaging 70.5° F.]

Date of immersion.	Date of removal.	Date of examination.	Dead larvæ.		Living larvæ.		Number days immersed.	Number fruits examined.
			Third instar.	Second instar.	Third instar.	Second instar.		
Jan. 15	Jan. 16	Jan. 17	16	15	239	63	1	22
Do	Jan. 17	Jan. 18	21	19	139	52	2	37
Do	Jan. 18	Jan. 19	155	46	6	0	3	24
Do	Jan. 19	Jan. 20	256	117	1	0	4	29
Do	Jan. 20	Jan. 21	317	197	0	0	5	41
Do	Jan. 21	Jan. 22	512	261	0	0	6	61

TABLE XI.—*Effect of submergence in ordinary soft water upon pupæ of the melon fly at a mean temperature of 78° F.*

Lot No.	Number of pupæ under observation.	Date of pupation.	Date of immersion.	Date of removal.	Number of adults emerging.	Date of emergence.
1	396	June 19–22	June 24	June 26	9	June 30
					90	July 1
					108	July 3
					19	July 4
					4	July 5
					3	July 6
					1	July 8
2	106	do	do	June 27	32	July 3
					15	July 4
					8	July 5
					4	July 6
3	52	do	do	June 28	2	July 3
					7	July 4
					1	July 5
					3	July 6
					1	July 7
4	77	do	do	June 29	1	July 10
5	91	do	do	June 30	0	
6	79	June 22–24	do	June 26	2	July 5
7	130	do	do	June 27	1	July 7
8	26	do	do	do	1	July 3
9	15	do	do	June 28	1	July 12
10	148	do	do	do	0	
11	101	do	do	June 29	0	
12	117	do	do	June 30	0	
13	170	do	do	July 1	0	

Burial in soil.—Van Dine (19) recommended that all melons and vines infested with the melon fly should be buried to the depth of several inches. Severin (45) has shown quite conclusively that

unless great care is taken thoroughly to tamp soil filled in over such infested material adults can emerge from pupæ and finally burrow their way to the surface from a depth of from 2 to 3 feet of dry sand; 34, 8, and 5 adults, respectively, from lots of 500 pupæ buried 2 feet deep succeeded in reaching the surface through dry sand, wet sand, and soil. Fifty-four 3-day-old pupæ were placed in the center of 10 square inches of heavy black soil, such as is found in the market-garden section of Waikiki. On drying out this soil hardened so that no adults were able to emerge. One hundred larvæ which had emerged ready for pupation were placed on the surface of the same heavy black soil just mentioned, which had been thoroughly wet, as though well irrigated. All the larvæ pupated on or close to the surface and 70 yielded adults. The soil was so tenacious on drying that the remaining 30 per cent which were just beneath the surface were unable to emerge.

Burial of the host for the destruction of the immature stages of the melon fly is not a method of control to be recommended. The labor necessary properly to bury infested material is so great that few lots will be buried to a sufficient depth, and cracks formed in the soil by rapid decay and settling furnish avenues for the escape of adults from fully 95 per cent of all material, even when buried in the most tenacious soils.

Traps.—Howlett states[1] that he was able in India to attract the males of the two closely related fruit flies, *Dacus zonatus* Saund. and *D. diversus* Coq., by exposing citronella oil. He was not able to attract specimens of either sex of the melon fly. Although he was successful in attracting these two species with citronella oil, he failed to get any reaction with such individual derivatives of this oil as were obtainable (citrol, citronella, geraniol, citronellaldehyde, citronellol). Later he believed that he had found the actual substances which are responsible for attracting these two fruit flies in iso-eugenol and methyl-eugenol. By exposing the closely related eugenol he succeeded in attracting the male of an apparently new species. Samples of eugenol sent by Howlett to Severin and given the writers by the latter gentleman failed to attract melon flies when exposed in infested districts.

The mango fruit fly (*Dacus ferrugineus* Coq.) was found by Froggatt (26) to be attracted by citronella oil, but Illingworth states[2] that the railroad worm (*Rhagoletis pomonella* Walsh) avoids citronella oil. It is now well known that the males only of the Mediterranean fruit fly are attracted in any numbers to ordinary kerosene. In Honolulu the writers have seldom caught adults of the

[1] Howlett, F. M. The effect of oil of citronella on two species of Dacus. Trans. Ent. Soc. Lond., 1912, Pt. II, p. 412–418, pl. 39, 40. 1912.

[2] Illingworth, James F. A study of the biology of the apple maggot, etc. Cornell Univ. Agr. Exp. Sta. Bul. 324, p. 160. 1912.

melon fly in this oil, although they have had traps hung throughout the infested district for many months. Severin was not able to catch a sufficient number of melon flies in various oils to feel that they were in any way actually attracted. He used the following oils: Citronella, turpentine, coconut, whale, fish, kerosene about 120° Baumé, gasoline about 86° Baumé, and benzine about 63° Baumé. Turpentine, gasoline, and benzine caught no flies. The other oils, exposed over a 5-day period, caught from 2 to 5 individuals, representing both sexes.

Ordinary flytraps baited with diluted molasses and hung about infested fields were found by Severin to be worthless.

Protection of fruit by covering.—The attack upon cucurbits of all varieties is so universal in Hawaii that the female bloom in all species except the cucumbers should be covered before the corolla unfolds or immediately after. During the warmer portion of the year the bloom of cucurbits should be protected at least 3 or 4 days before the flower unfolds in order to insure protection. At present many fruits are so covered, but rather indifferently and ineffectually, as proved by an examination of fruits beneath the coverings. Thus during April only 9 out of 43 fruits of the Chinese melon (*Momordica* sp.) that had been covered were sound, while at Waipahu on the same date 119 out of 692 young protected watermelons were actually free from infestation. Certain Japanese growers ward off attack by burying the young fruit in the soil or surrounding it by straw and trash until it is sufficiently old to need no further protection. However, the usual practice among both Japanese and Chinese growers is to place over the developing bud or the recently opened flower a piece of cheesecloth or other fabric. This averages in size about 6 to 7 inches square and is placed lightly over the fruit without any attempt to attach it to the plant, although in certain cases it may be weighted on the edge with earth. The most successful of the protective coverings are those shown in Plate XXIV. In this case the Momordica vines are grown in bushes where the young fruits can be easily found and inclosed in the long case made from newspapers. These cases are left open at the lower end, but are never entered by the adult flies.

The protection of fruits by covering with soil, paper, or cloth is a great labor-consuming operation that at present actually protects less than 25 per cent of all fruits covered, except certain Chinese marrows. This method is, however, at present the only one which can be applied with any degree of success, and could be made far more successful were it applied more intelligently. In a slightly cooler climate a very much higher percentage of fruits could be saved.

SUMMARY.

The melon fly (*Bactrocera cucurbitae* Coq.) is found well distributed over India, which is considered its native home. It is at present found in India, Ceylon, Java, Timor, Northern Australia, Singapore, the Philippine Islands, southern China, Japan, and the Hawaiian Islands. It was introduced into the Hawaiian Islands from Japan about 1895, and by 1897, when it was first observed, it was already a serious pest. Up to the present time it has been allowed to increase unrestricted, and because of the equable climate and abundant food supply has become a serious pest of cucurbitaceous crops, cowpeas, string beans, and tomatoes. It is impossible to overstate the destructiveness of the melon fly to cucurbitaceous fruits under Hawaiian littoral conditions, where these can be brought to maturity only with the exercise of the greatest care on the part of market gardeners.

It has been estimated that the melon fly causes a loss of about three-quarters of a million dollars in a territory smaller than the State of Rhode Island. It is a pest of prime importance that is being intercepted each year by officers of the Federal Horticultural Board in ships arriving at the California coast from Honolulu and Hilo, and there is, therefore, great danger of the melon fly being introduced to the continental United States.

During the warmest seasons in Hawaii, when the mean temperatures average about 79.5° F., the egg, larval, and pupal stages may be passed in as few as 12 or as many as 28½ days, according to the individual and host conditions. At mean temperatures lower than 79.5° F. the duration of the immature stages may be greatly increased. Thus at 51.6° F. the pupal stage alone may require 59 days and the egg 11 days, while at 56° to 62° F. the first and third larval stages may require 27 and 23 days, respectively. Under varying conditions of host, temperature, and humidity the immature stages may be lengthened from a minimum of 12 days to 3½ to 4 months. Adults may live as many as 431 days, although the duration of adult life is variable and may be but a few days. Adults deprived of food and water never live more than 102 hours or more than 120 hours without food but with water. This is also true of adults which have been feeding for some time when placed under starvation conditions. The complete life cycle may, therefore, occupy from 443 to 459 days in the case of most hardy individuals passing the egg, larval, and pupal stages during the warmest seasons, but longer when these stages are passed during colder seasons.

Adults feed principally upon the juices of host plants, nectar of flowers, and honeydew secreted by a large number of insects. While the melon flies are rapid fliers and are found often far from their host plants, they appear to arrive at these points as the result of

roving rather than by long-sustained flights. During the warmest seasons they are active in feeding and ovipositing chiefly during the early morning and late afternoon hours. In captivity they mate about sunset and when fed upon papaya and water, copulate only when about 20 or more days old, with the mean temperature averaging 75.5° F. and the relative humidity 69.3 per cent. No eggs were obtained from females under these conditions until 32 days after emergence. During the winter, also, when fed upon papaya and water, when the mean temperature was 71° F. and the relative humidity 78.5 per cent, no eggs were deposited until 44 days after emergence. However, when fed on cucumber, in captivity, mating will commence when the adults are only 10 days old and egg-laying begins the following day or only 11 days after emergence, when the mean temperatures average 76.4° F. and the relative humidity is 69.1 per cent. Having once begun ovipositing, adults continue to deposit batches of from 1 to 37 eggs every few days throughout life. One female deposited eggs when 398 to 400 days old. Another, emerging on May 25, 1914, deposited 687 eggs between July 15, 1914, and February 27, 1915. It is estimated that particularly hardy individuals may deposit as many as 1,000 eggs. The average number of eggs deposited is much less and extremely variable.

Adults deposit their eggs within the tissues of the host fruit in cavities made with the aid of a sharp ovipositor. Eggs may be deposited in all portions of the plant and fruit, including the crown, leaf petioles, stalks, and blossoms. If deprived of host plants adults will oviposit, although less frequently, upon other objects, at least in confinement. They were able to keep alive by feeding on the food supplied them in the laboratory during a period of what happened in experimental work to be from 13 to 31 to 37 weeks when no host plants were available for oviposition, and began ovipositing at a normal rate as soon as host plants were available.

Larvæ upon hatching usually burrow to the center of the host plant or fruit, although the place where they feed is determined largely by the moisture content of the host. In young seedlings they may burrow into the taproot and kill the plant. In succulent plants they burrow through the leaf petioles and stalks and bring about a progressive pruning back of vines by causing the death of affected parts. The staminate and pistillate bloom and the fruits are variously affected, as described and illustrated elsewhere. After passing through three instars the larvæ leave the host to pupate in the soil, usually beneath the host, at a depth ranging downward to 2 inches. Larvæ are aided in leaving the fruit and seeking suitable places for pupation by their ability to jump, in stages, from 6 to 8 inches. If they are not able to enter the soil they will pupate upon any hard surface, such as a floor, corners of fruit cases, burlap coverings, etc.

Since there are as many as 8 to 10 generations of the melon fly a year, it is evident that it can multiply very rapidly. No agencies have been found to be working at the present time in Hawaii that bring about, even periodically, a great natural reduction in the abundance of melon flies. In colder climates cold weather will prove a marked and valuable control factor. No parasites are known in Hawaii. Predacious enemies and several forms of mortality recorded are of no practical value under Hawaiian conditions. Search for parasites is now in progress and it is hoped that future introductions of melon-fly parasites may prove beneficial.

No satisfactory artificial measures have been successfully applied in combating the melon fly under Hawaiian conditions. Poisoned-bait sprays promise to yield effective results under other cultural conditions. At present cucurbits can only be grown by the use of coverings of various sorts for the protection of the very young fruit. Trapping of adults and killing adults by sprays have yielded negative results, while killing the immature stages by submergence in water, by burial in soil, or by cold-storage temperature are methods to be applied in lessening the abundance of the pest after infestation has occurred. Artificial methods of control are not likely to prove satisfactory in Hawaii so long as the growing of the chief host plants remains in the hands of uneducated oriental laborers who do not practice clean cultural methods or cooperate in applying remedial measures.

BIBLIOGRAPHY.

(1) CLARK, B. O.

1898. *In* The Hawaiian, vol. 1, No. 27, p. 6.

The Hawaiian was a newspaper published only during 1898. Mr. L. H. Mesick, Hawaiian Gazette Co., Honolulu, its editor, possesses the single known complete file. One section of the paper was known as the official bulletin of the Bureau of Agriculture (now the Board of Agriculture and Forestry). The reference consists of correspondence containing the first information published regarding the presence of the melon fly in the Hawaiian Islands, or elsewhere, and is as follows:

LAUPAHOEHOE, *August 8, 1898.*

Prof. KOEBELE, *Honolulu.*

DEAR SIR: We have a new pest that has lately come here in the shape of a fly like a yellow jacket, only not so large. It punctures pumpkins, squashes, bean, tomatoes, watermelons, and all other plants of this nature. It lays eggs inside, which form maggots like the samples I send you. You can judge of their work where the things are growing. Can you suggest any remedy? I send you some samples of their work by the S. S. *Kinau.*

Yours, truly,

L. C. SWAIN.

HONOLULU, *August 11, 1898.*

L. C. SWAIN, Esq., *Laupahoehoe, Hawaii.*

DEAR SIR: Yours of the 8th instant at hand and contents noted. Prof. Koebele is now in the States, but as I have personal experience with the fly you mention and consulted with Prof. Koebele in regard to it, I can state he told me of no remedy except covering the vines, and of course this is not at all practicable except for a few vines in a garden. I tried a spray of whale-oil soap, thinking the odor might keep the fly away, but it did not. I shall try a Paris-green solution, 1 pound to 200 gallons of water, keeping it stirred frequently, and apply with a spray pump. This will kill the eggs and young larvæ of the codling moth on apple and other fruits, and possibly may do so in this case. The great difficulty in this climate is that frequent showers wash off the poison, and it has to be repeated frequently. The Paris green can also be applied as a powder, mixed with flour or air-slaked lime, in the proportion of 1 part of Paris green to 100 of flour or lime. I would advise collecting all infested squashes and feeding to pigs or other animals or bury them so deep the fly can not get out when it hatches. If all who grow the crops which it breeds in would do so, I think it could be at least checked; the great difficulty would be to know if there is any

wild fruit, etc., upon which it deposits its eggs for development. I have not observed it attacking anything but the cucumber, melon, and squash family.

The following life history, which I have learned by experimenting in a "hatchery," may interest you if you have not already determined the same for yourself. The fly which you describe is more like a small-sized botfly than a wasp, and will be seen hovering about the vines of muskmelons, squashes, etc., and when disturbed darts away very quickly, so rapid, in fact, one can scarcely follow it with the eye. It stings not only the fruit with its ovipositor, but also the young and tender growth of the vines, depositing a number of eggs, which soon hatch into small white maggots that feed on the tissues of the plant or fruit, causing it to decay. After the maggot has attained its growth, it descends into the soil, where it develops into a small chrysalis of a light yellowish-brown color, and in about 10 or 12 days comes out a perfect insect, ready to repeat its mission of destruction. I do not know how many generations it will produce in a year, but in the warmer and drier districts I believe it will breed the year through, except possibly a while during the winter months, and then its development is only retarded by the cooler weather, which prevents the chrysalis maturing so rapidly.

If you will take a squash or other specimen with the eggs or young maggots in the same, placing it in a box containing 2 or 3 inches of loose, dry soil, keeping it covered with a piece of glass, you can soon learn for yourself its life history, and perhaps make observations that may lead to means of successfully combating the pest.

Yours, respectfully,

BYRON O. CLARK,
Secretary and Commissioner of Agriculture.

(2) COQUILETT, D. W.

1899. A new trypetid from Hawaii. *In* Ent. News, v. 10, No. 5, p. 129–130.

This article, which is technical and contains the original description of *Dacus cucurbitæ,* is as follows:

Dacus cucurbitæ n. sp. Head light yellow, the occiput, except the sides and upper margin, reddish yellow, an ocellar black dot, front marked with a brown spot in front of its center and with three pairs of orbital brown dots, a black spot on each side of the face near the middle, and a brown spot on the middle of each cheek; antennæ, palpi, and proboscis yellow, the latter mottled with brown. Thorax reddish yellow, the humeri, a median vitta on the posterior half of the mesonotum, another on each side above the insertion of the wings, uniting with an irregular band which extends upon the pleura to the upper part of the sternapleura, also a large spot on each side of the metanotum, encroaching upon the hypopleura, light yellow; scutellum, except its extreme base, light yellow, bearing two bristles. Abdomen light yellow on first two segments, reddish yellow on the others, the extreme base, a fascia at the bases of the second and third segments, usually a lateral spot on the fourth and fifth, also a dorsal vitta on the last three segments, blackish or brownish; first segment of the ovipositor of the female slightly longer than the fifth segment of the abdomen. Wings hyaline, the apex of the subcostal cell from a short distance in front of the apex of the auxiliary vein, the marginal and submarginal cells, the median third of the first basal cell, and a large spot in upper outer corner of the first posterior cell, brown; anal cell brown, this color encroaching on the third posterior cell and bordering the sixth vein almost to its apex; posterior cross vein bordered with brown, this color extending to the hind margin of the wing; upper end of the small cross vein also bordered with brown. Halteres light yellow. Legs light yellow, the broad apices of the femora and the last four joints of the tarsi reddish yellow, hind tibiæ reddish yellow or dark brown. Length 6 to 8 mm.

Honolulu, Hawaii. Two males and two females bred by Mr. George Compere from larvæ living in green cucumbers. Type No. 4207, U. S. Nat. Museum

(3) HOWARD, L. O.

1900. A dipterous enemy of cucurbits in the Hawaiian Islands, *In* U. S. Dept. Agr. Div. Ent. Bul. 22, n. s., p. 93–94.

In this short account Dr. Howard gives data on the prevalence of the melon fly about Honolulu, secured by George Compere, at the time of his visit to the Hawaiian Islands in November, 1898. Reference as follows:

March 13, 1899, we received from Mr. George Compere, Honolulu, Hawaiian Islands, specimens of what is locally known as the melon or cucumber fly. Our correspondent, writing under date of February 14, 1899, states that this is a very serious pest with vegetable growers, as it destroys more than 75 per cent of the watermelons, cantaloupes, and cucumbers grown in those islands. He writes, in substance, that the parent flies are to be found at all seasons of the year, and that they puncture the cucumber, which is the only plant on which our correspondent has observed the species, on the upper side, and generally near the stem end, this operation taking place when the cucumber is about half or two-thirds grown. In the punctures thus made they deposit their eggs, which soon hatch into minute footless white maggots. Their presence in the cucumber is manifested by a small yellow spot where the puncture was made. Twenty-seven minute maggots were counted in one of these punctures. In one cucumber that had been punctured three times in different places, 116 of these maggots were counted. These maggots eat out the entire inner substance of the fruit with the exception of the seeds, leaving only the outer skin, which turns yellow and decays, when a slight touch or a few drops of rain will cause it to collapse. By that time the maggots have all attained their growth, and if any of them become exposed to the sunlight they immediately draw themselves together and, after the manner of the cheese maggot and other species that might be mentioned, spring in all directions, jumping as high as 3 feet. If the skin of the cucumber be left intact they will emerge from the decayed pulp on the underside and burrow at once into the earth for pupation. Fourteen days after placing maggots in a breeding jar, with soil kept constantly moist, Mr. Compere succeeded in obtaining the adult flies.

In the conclusion of this letter our correspondent adds, as a warning, that watermelons, cantaloupes, and cucumbers should never be allowed to be shipped from the

Hawaiian Islands into the United States. It is quite probable that this insect could be introduced into several of our Southern States or recently acquired insular possessions, and it is one of those species for which quarantine inspectors should be on the lookout. No class of vegetables, if we except cabbages and botanically related plants, are so badly infested with insects as are the cucurbits, and the introduction of another new pest is most undesirable.

The insects were referred to Mr. Coquillett, of this office, who after careful examination pronounced the species an undescribed Trypetid. He has accordingly given it the name of *Dacus cucurbitæ*, and has published a description of it in the Entomological News for May, 1899, under the title "A New Trypetid from Hawaii."

(4) KOEBELE, ALBERT.

1900. Report of Prof. A. Koebele, entomologist. *In* Rpt. Comr. Agr. and Forestry, Hawaii, p. 36–49.

Among injurious pests treated he calls attention to the fact that *Dacus cucurbitæ* is the only species of fruit fly so far known in Hawaii, that it is almost impossible to raise cucurbitaceous fruits without proper protection to the plants, and suggests cooperation in clean cultural methods as the only feasible manner of combating the pest.

(5) HOWARD, L. O.

1901. Diptera collected in Hawaii by H. W. Henshaw. *In* Proc. Ent. Soc. Washington, v. 4, no. 4, p. 490.

Among the Diptera *Dacus cucurbitæ* Coq. is listed with the statement: "Five specimens. Described from Hawaii."

(6) GRIMSHAW, P. H.

1901. Fauna Hawaiiensis. (v. 3, pt. 1, 77 p., 3 pl. Cambridge.)

Reference consists merely of copy of (2) and statement of Howard (5).

(7) CRAW, ALEXANDER.

1902. Horticultural quarantine reports. *In* Bien. Rept. Bd. Hort. Cal., v. 8, 1901–2, p. 187–204.

Reference consists of a paragraph of seven lines, giving the first official record of the interception by quarantine officers of melon-fly infested material from Honolulu at San Francisco. Reference as follows (p. 198):

We occasionally find a melon in the possession of passengers or crews from Honolulu, which we destroy. No melons, cucumbers, or summer squashes have been received as freight from Honolulu since we destroyed the shipment that arrived on February 28, 1899, on the S. S. *Australia*, infested with melon maggots (*Dacus cucurbitæ*). In Honolulu this pest destroys 75 per cent of their crop. It is not found in North America.

(8) PERKINS, R. C. L.

1902. Insects. *In* Rept. Governor of Territory of Hawaii for 1902. Ann. Rpts. U. S. Dept. Int., pt. 2, p. 360.

An 8-line reference, recounting difficulty of growing cucumbers, except under cover, as a result of melon-fly attack. "Its true home is no doubt either Japan or China. At Hongkong a species is found almost identical in size, color, and form, and which only differs in having an additional pair of bristles on the scutellum. Parasites of the melon fly could no doubt be procured from that country."

(9) SMITH, J. G.

1902. *In* Ann. Rpt. Hawaii. Agr. Exp. Sta., U. S. Dept. Agr. Off. Exp. Stas. Rpt., 1902, p. 324.

Four-line reference as follows: "A fly is doing great damage to the cucurbits by stinging and depositing its eggs in the young fruit. The larvæ, on hatching, burrow into the tissue, causing decay. As a result a good watermelon brings from 50 cents to $1 on the fruit stands of Honolulu.

(10) SMITH, J. G.

1903. *In* Ann. Rpt. Hawaii. Agr. Exp. Sta., 1903, U. S. Dept. Agr. Off. Exp. Stas. Rpt, 1903, p, 417.

A 2-line reference to an investigation of melon-fly ravages at Wahlawa, Oahu.

(11) VAN DINE, D. L.

1904. Insecticides for use in Hawaii. *In* Hawaii. Agr. Expt. Sta. Bul. 3, 21 p., 7 fig.

A 5-line reference as follows, p. 7:

Watermelons and muskmelons are a luxury, a good melon bringing 50 cents to $1 at the fruit stands in Honolulu. These products could be raised in certain sections, in quantities great enough to bring them within the reach of every table, were it not for the attack of the melon fly (*Dacus cucurbitæ*).

(12) Van Dine, D. L.

1904. Entomological work. *In* Ann. Rpt. Hawaii. Agr. Expt. Sta., p. 372–379.

Reference as follows (p. 376): "The melon fly (*Dacus cucurbitæ*) is a true fly of the family Trypetidæ. The larva infests the fruit of all plants of the family Cucurbitaceæ; destructive also to beans and tomatoes."

(13) Craw, Alexander.

1905. Report of superintendent of entomology. *In* 1st Rpt. Bd. Agr. and Forestry Hawaii, p. 136–146.

Reference is as follows (p. 138): "The melon fly (*Dacus cucurbitæ*) was unfortunately introduced here a few years ago from Japan. That pest has practically stopped the production of muskmelons here. It also attacks other melons, besides cucumbers, squash, tomatoes, and even string beans."

(14) Krauss, F. G.

1905. The vegetable garden. *In* Hawaii. Forester and Agr., v. 2, no. 11, p. 353–361.

The author states in a discussion of melons that "were it not for the ravages of the cut-worms, plant lice, and the melon fly these crops would be delightful to grow in Hawaii, but our advantages from the absence of frost are about offset by the prevalence of insect pests."

(15) Terry, F. W.

1906. A preliminary account of insects of economic importance in the Hawaiian Islands. *In* Haw. For. and Agr., v. 3, no. 2, p. 35–45.

Discusses *Dacus cucurbitæ* in 24 lines of print (p. 44). "Since its arrival it has practically stopped the raising of melons, cucumbers, squashes and tomatoes in many localities, unless these plants are carefully screened from the attacks of the fly." Popular notes on life history and description of very general nature.

(16) Van Dine, D. L.

1906. The melon fly (*Dacus cucurbitæ* Coquillett). *In* Haw. For. and Agr., v. 3, no. 4, p. 127–129.

A 3-page popular account of a most general nature. States that during last season the crop of melons exceeded any previous crop since the advent of the fly, probably due to the perseverance of Japanese growers in protecting their melons from the fly at or immediately after the setting of the fruit.

(17) Craw, Alexander.

1907. Reports of horticultural quarantine inspection work. *In* Hawaii. For. and Agr., v. 4, no. 5, p. 113–116.

From dead specimens of the "melon fly" (*Dacus cucurbitæ*) received by this division from the government entomologists of India, we learn of the existence of several parasites that prevent its seldom or ever becoming a pest there. An effort should be made to introduce these parasites here by way of Hongkong. This would be a difficult experiment, owing to the great distance, but the undoubted benefit to the melon industry of this Territory, in case these parasites were successfully introduced and established, would justify the expenditure of considerable money in the attempt to control this pest.

(18) Maxwell-Lefroy.

1907. The more important insects injurious to Indian agriculture. *In* Mem. Agr. Dept. India, Ent. Ser., v. 1, p. 113–252, 80 fig.

Page 228 states that this is a sporadic and occasionally serious pest which hibernates during cold months and is found in hot weather and rains. Gives distribution as "Nasik, Pusa, Hathwa, Surat, Umballa. Probably throughout India."

(19) Van Dine, D. L.

1908. Report of the entomologist. *In* Ann. Rpt. Hawaii. Agr. Expt. Sta., 1907, p. 25–51, 3 fig., 2 pl.

The melon fly, p. 30–35: A good concise article of 5½ pages, containing copies of (1), (2) and (17), the first illustrations of adult, eggs, larva and puparium ever published, a complete bibliography to date, besides general statements regarding ravages and control.

(20) HOWLETT, F. M.

1909. Diptera. *In* Maxwell-Lefroy's Indian Insect Life, p. 545–664, pl. 58–71, fig. 348–423.

No text regarding *Dacus cucurbitæ* but figures adult female, eggs in gourd, larva and pupa, together with anterior and posterior spiracles of pupa, p. 633, fig. 4, 8.

(21) KIRKALDY, G. W.

1909. Entomological notes. *In* Haw. Planter's Record, v. 1, no. 2, p. 32.

Short note stating that some parasites of the melon fly left with the Hawaiian Board of Agriculture and Forestry by Geo. Compere were being investigated by the Entomological Division of the Hawaiian Sugar Planters' Association. (See (23) for further information.)

(22) BLACKMAN, L. G.

1909. Our melon pest. *In* Hawaii. Forester and Agr., v. 6, no. 8, p. 281.

Calls attention to an estimated loss of three-quarter million dollars annually to Hawaii as a result of melon-fly attack and to the need of a search for and the introduction of parasites of the melon fly.

(23) KOTINSKY, J.

1909. Report of the superintendent of entomology for July, 1909. *In* Hawaii. Forester and Agr., v. 6, no. 9, p. 358–361.

Gives result of investigation referred to in (21). Records the rearings from pupæ of *Ceratitis capitata* sent by Geo. Compere from West Australia. Consignment on arrival at Honolulu, June 24, 1909, was turned over to the Entomological Division of the Hawaiian Sugar Planters' Association. Summarizes investigations made by O. H. Swezey, of the Hawaiian Sugar Planters' Association (see p. 364–365), by saying that a few adults of *Ceratitis capitata* emerging first were allowed to die in the rearing vials before removal; that although 115 specimens of *Chalcis* (probably *Tetrastichoides* sp.) emerged and were placed with melon-fly maggots no mating or oviposition was noted and no maggots became parasitized. Seven specimens of a braconid (*Apodesmia* sp.) were reared, but no mating or attempts at oviposition were noted, and no parasitism followed the confinement of these parasites with cucumbers infested with maggots of *Dacus cucurbitæ*.

(24) BEZZI, M.

1909. Le specie dei generi Ceratitis, Anastrepha e Dacus. *In* Bol. Lab. Zool. Portici, v. 3, p. 273–313.

Dacus cucurbitæ, p. 294 and 300. Purely systematic reference.

(25) VAN DINE, D. L.

1909. Report of the entomologist. *In* Ann. Rpt. Hawaii. Agr. Expt. Sta., 1908, p. 17–41.

Page 32, a 5-line reference as follows: "It is believed that at the present price of melons it would pay to grow muskmelons at least under cover, fertilizing the flowers by colony of bees."

(26) FROGGATT, W. W.

1909. Report on Parasitic and Injurious Insects. Dept. Agr. N. S. Wales, 1907–1908, p. 53, 54, 56, 84–85, pl. 11, figs. 6, 7.

Records *Dacus cucurbitæ* from gardens about Allahabad, India, and Jaffna, Ceylon. States that *Dacus cucurbitæ* was not attracted to citronella oil, although other species of *Dacus* were; that Muir found India the native home of *D. cucurbitæ*, and that his own later investigations showed that it was widely distributed over India and Ceylon; found *Dacus cucurbitæ* wherever melon gardens were examined in Central and Northwestern India; reared it from melons, cucumbers, bitter gourd, and eggplant.

(27) MARSH, H. O.

1910. Report of the assistant entomologist. *In* Rpt. Bd. Comrs. Agr. and Forestry, Hawaii, p. 152–159.

Forty-three lines of print calling attention to utter disregard by oriental gardeners of clean cultural methods and resultant increase of *Dacus cucurbitæ* about Honolulu. Discusses results of spraying with poison baits and use of trap crop. In the latter cantaloupes were used with cucumbers with negative results, since both crops were entirely destroyed. Spraying experiments in which a solution of molasses 1 quart, Paris green ¼ ounce, and water 1½ gallons was used, gave negative results, although applied daily from September 9 to October 14. A solution with arsenate of lead also gave negative results.

(28) EHRHORN, E. M.

1910. Report of the superintendent of entomology. *In* Hawaii. Forester and Agr., v. 7, no. 11, p. 336–338.

Record of rearing one adult melon fly from sweet orange from Kaimuki, Oahu.

(29) PERKINS, R. C. L.

1911. The Mediterranean Fruit Fly. *In* The Hawaii. Planters' Record, v. 4, no. 3, p. 140–144, 3 fig.

Article is entirely on *Ceratitis capitata,* but contains by way of illustration for comparison a good figure of the adult female *Dacus cucurbitæ.*

(30) BANKS, NATHAN.

1912. The Structure of Certain Dipterous Larvæ, with Particular Reference to those in Human Food. U. S. Dept. Agr. Bur. Ent. Tech. Ser. 22, 44 p., 8 pl.

Reference as follows, p. 32, pl. 5, fig. 101, 102, 104:

Dacus cucurbitæ Coq. Head bilobed from above, each lobe bearing a distinct antenna; mandibles two, distant; anterior spiracles long, with about 20 lobes. Ventral segments 6 to 12 with swollen spinulose areas. The last segment shows below a transversely elliptical spinulose area, rather depressed, and containing two approximate, flat, rounded tubercles; tip of body rounded, with a low, broad swelling at each lower corner; the stigmal plates are approximate, each with three short slits, pointing toward those of the opposite plate.

From melons in Hawaii.

Gives figures of side view of head, anterior spiracle, and stigmal plate of larva.

(31) WEINLAND, H. A.

1912. The fruit fly menace and preventive measures. *In* Mo. Bul. State Com. Hort. Cal., v. 1, no. 5, p. 156–159.

While dealing chiefly with *Ceratitis capitata,* Weinland has the following to say about *Dacus cucurbitæ:* "The melon fly has been a pest on the Hawaiian Islands for as many as 25 years and has become established on all the islands of the group. It is particularly destructive to melons and certain vegetables. On March 28, 1910, Quarantine Order No. 4 was issued barring from the State watermelons, muskmelons, cucumbers, and tomatoes from these islands or from any other place in which the fly is known to exist."

(32) COOK, A. J.

1912. The work of the State commissioner of horticulture. *In* Mo. Bul. State Com. Hort. Cal., v. 1, no. 8, p. 372–377; no. 9, p. 533–539.

Two references identical and as follows: "I am happy to inform you that we have enlisted the interest and action of other Pacific Coast States and of British Columbia, and so feel that we are in less danger of an invasion of the Mediterranean fruit fly and of the melon fly (*Dacus cucurbitæ*) via other than our own ports through the interest and action of horticulturists of other States."

(33) COMPERE, GEO.

1912. A few facts concerning the fruit flies of the world. *In* Mo. Bul. State Com. Hort. Cal., v. 1, no. 10, p. 709–733, fig. 204–219.

Pages 709–710, discovery of *Dacus cucurbitæ* in Honolulu in November, 1898; p. 723, record of collections about Poona, India; p. 845, record of collections at Colombo, Ceylon; p. 909, record of rearing material collected at Bangalore, India; states that he found the melon fly a rather serious pest at Macao and Canton, but "not to the extent it is in the Hawaiian Islands." Figure 212 reproduces photo (2) wing of melon fly from India and (3) from Hawaii.

(34) GREEN, E. E.

1912. Report of the government entomologist. *In* Rpt. Dept. Agr. Ceylon, pt. 4, 1911–1912, p. 2–5.

Lists the pumpkin fly (*Dacus cucurbitæ* Coq.) as destructive to fruits of vegetable marrows.

(35) ESSIG, E. O.

1913. Some interesting fruit flies. *In* Mo. Bul. State Com. Hort. Cal., v. 2, no. 11, p. 726.

Gives C. F. Baker as authority for information that *Dacus cucurbitæ* Coq. is abundant in the Philippine Islands.

(36) Bezzi, M.

1913. Indian trypaneids (fruit flies) in the collection of the Indian Museum. *In* Mem. Indian Mus., v. 3, no. 3, p. 53–175, pl. 8–10, 3 fig.

Bactrocera cucurbitæ Coquillett, p. 96–97, pl. 8, fig. 7 (wing):

"A proportionally large species which can be easily recognized from all other known Indian species by the posterior cross-vein of the wings being widely bordered with brown. Vertical, thoracic, and scutellar bristles black. Third abdominal segment of the male with a row of black bristles; anal stripes dilated at tip, but less abruptly than in the preceding species [*mangifera*]." States that this species has been found widely distributed over India and Ceylon, and that this region is its original home. "In the collection are many specimens from Calcutta, caught in April, May, June, and September; others from Durjbana, Nepal Terai, Ranchi; Kumdlik, Nepal Terai, in March; Bhogaon, Purneah district, N. Bengal, in October; Allahabad, United Provinces, in August; Nepalganj, Nepal Frontier, 22–xi–11; Siripur; Saran, N. Bengal, 26–ix–10; Adra, Manbhum district, 12–x–09; Bombay, in gourds, 12–x–03; Peradeniya, Ceylon, 10–i."

States, on page 366, that while he reared four species of Dacus from Fijian fruits he did not find Cucurbitaceæ.

(38) Muir, F.

1914. Observations in Formosa. *In* Hawaiian Planters' Record, v. 10, no. 4, p. 274–281.

In 3-line reference, p. 281, states "*Dacus cucurbitæ* and *Dacus diversa* (*c*) are both common and do harm—the former to cucumbers, melons, etc.; the latter to citrus fruits. No parasites are known to attack them."

(39) Bridwell, J. C.

1914. Report for the period from October 1 to December 31 [1913]. *In* Hawaii. Bd. Agr. and Forestry Bul. 3, p. 154–160.

States that development of melon fly is not retarded by winter weather and that melon-fly pupæ may be used experimentally in rearing parasites for *C. capitata.*

(40) Rutherford, A.

1914. Report of the entomologist. *In* Rpt. Dept. Agr. Ceylon, July 1, 1912, to December 31, 1913, p. 9–12.

Lists *D. cucurbitæ* among various insects of economic importance.

(41) Dammerman, K. W.

1914. Het Vraagstuk der Fruit-vliegen voor Java. Dept. van Landbouw, Nijverheid En Handel. Meddelingen van de Afdeeling voor Plantenziekten, no. 8, p. 7–8, pl. 2, fig. 1. (wing).

States that in Java has bred *Dacus cucurbitæ* from Momordica and Citrullus, and lists as feeding in melons, watermelons, and cucumbers. Article of value chiefly as reference to presence of pest in Java.

(42) Maskew, F.

1914. Report of investigations of the fruit-fly situation in the Territory of Hawaii. *In* Mo. Bul. State Com. Hort. Cal., v. 3, no. 6, p. 227–238.

Report deals chiefly with *Ceratitis capitata,* but contains the following: "The melon fly (*Dacus cucurbitæ*) is a source of great financial loss to the producers, and all of its hosts should be included in the list of material covered by the United States quarantine order."

(43) Fletcher, T. B.

1914. Some South Indian Insects. 565 p., 50 pl., 440 fig. Madras.

Page 354 states that the melon fly is a serious pest to cucurbits through southern India, where it passes through the egg, larval, and pupal stages in about 15 days. Recommends prompt gathering and deep burial of all infested fruits and protection of fruits by coverings of netting. Colored plate 26 gives good enlarged dorsal view of adult fly and figures of larvæ and pupæ. Illustrations same as appearing in (20), only enlarged and colored.

(44) Fullaway, D. T.

1914. Report of the entomologist. *In* Ann. Rpt. Hawaii. Agr. Exp. Sta., 1913, p. 18–21.

Lists of insects affecting various garden crops with approved notes. Lists *Dacus cucurbitæ* as affecting cabbage, eggplant, tomatoes, peppers, and cucumbers.

(45) SEVERIN, H. H. P., SEVERIN, H. C., and HARTUNG, W. J.
1914. The ravages, life history, weights of stages, natural enemies, and methods of control of the melon fly (*Dacus cucurbitæ* Coq.). *In* Ann. Ent. Soc. Amer., v. 7, no. 3, p. 177–207, pl. 27–31, 4 fig.

Most comprehensive paper dealing with *Dacus cucurbitæ* thus far published. Of special interest from standpoints of new and for most part original data and illustrations of pest's capacity for damage, and for data on length of egg, larval, and pupal stages, weights of various stages, and control by submergence in water, burial in sand and soil, traps, and poisoned sprays.

(46) BACK, E. A., and PEMBERTON, C. E.
1914. Life History of the Melon Fly. *In* Jour. Agr. Res., v. 3, no. 3, p. 269–274.

Preliminary to present bulletin, giving data on length of egg, larval, and pupal stages, and upon longevity, sexual maturity, and rate of oviposition of adults during the warmer periods of Hawaiian weather. First report of careful biological work in which the important influence of temperature is taken into consideration.

(47) FULLAWAY, D. T.
1915. Report of the entomologist. *In* Rpt. Hawaii. Agr. Exp. Sta., 1914, p. 43–50.

Reference as follows (p. 49): "The melon fly (*Dacus cucurbitæ*) has often been reported infesting the heart of cabbage, but the infestation is not at all common and is considered to be due to abnormal conditions in the plant and of a secondary nature."

(48) SEVERIN, H. H. P.
1915. Experiments in destroying fruit infested with fruit fly maggots. *In* Ent. News, v. 26, no. 2, p. 78–83.

Deals with both *C. capitata* and *D. cucurbitæ*. Contains 1¾ pages of compilation from other authors, 2½ pages taken verbatim from (34), and 1 page of conclusions and bibliography. Tables and figure appear in (34).

(49) MASKEW, F.
1915. Report of the quarantine division for the years 1912, 1913, 1914, and 1915, appearing in Mo. Bul. St. Com. Hort., Vols. II, III, and IV.

Records the interception at San Francisco of contraband material from Honolulu, containing living larvæ of *Dacus cucurbitæ* during July, 1912, June and September, 1913, and June, 1914. No melon flies were intercepted during 1915 unless covered by the "tomatoes infested by trypetid larvæ" recorded for November.

(50) HILL, G. F.
1915. Insect Pests of Plants. Northern Territory of Australia. Dept. External Affairs. Melbourne. Bul. no. 13, 16 p.

Dacus cucurbitæ Coq. is listed as pest of melons, pumpkins, and marrows, among some of the principal insect pests of trees and crops at present grown in the Northern Territory.

(51) BRYAN, W. A.
1915. Natural History of Hawaii. 596 p., 117 pl., Honolulu.

Six-line paragraph dealing in a general way with the melon fly as one of a number of important pests introduced into Hawaii, p. 387.

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